MACHINE DESIGN

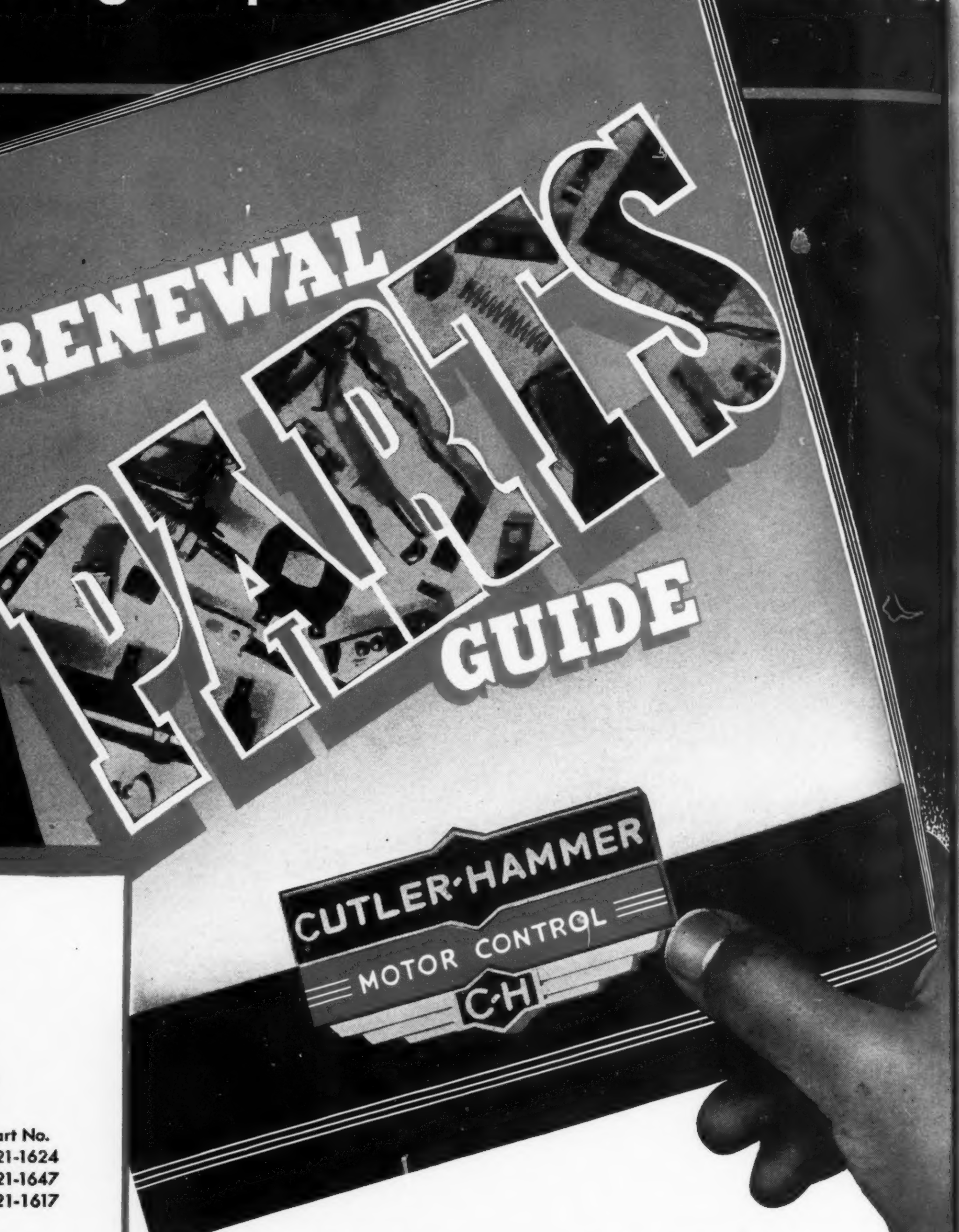
February 1944

In This Issue:

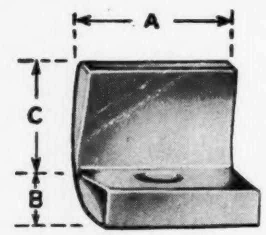
Designing for Stamping

Brittle Lacquer Stress Analysis

To speed up and simplify the ordering of parts for Motor Control



Free
Timely
Valuable



A	B	C	Part No.
½ in.	⅞ in.	⅞ in.	1321-1624
¾ in.	⅞ in.	⅞ in.	1321-1647
1 in.	⅞ in.	⅞ in.	1321-1617

Typical Illustration from the Renewal Parts Guide

Each part is shown in "lifelike" perspective so it can be easily matched up with the part to be replaced. Full dimensions are given to assure accurate part order number.

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WARTIME production imposes staggering demands on Motor Control and the men who keep it going. Thus the job of ordering renewal parts must be reduced to its simplest terms. This is just what the new Cutler-Hammer Renewal Parts Guide does for you.

It illustrates standard C-H parts, with dimensions, so clearly anyone can easily identify the parts needed and order them by the correct parts number. This short-cut guide is a boon to busy maintenance men. It helps eliminate errors in ordering and avoids delays in delivery...insures having correct parts at hand. Moreover, it includes many practical maintenance ideas for prolonging the life of controllers, resistors, magnets, brakes and clutches.

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MACHINE DESIGN

THE PROFESSIONAL JOURNAL OF CHIEF ENGINEERS AND DESIGNERS

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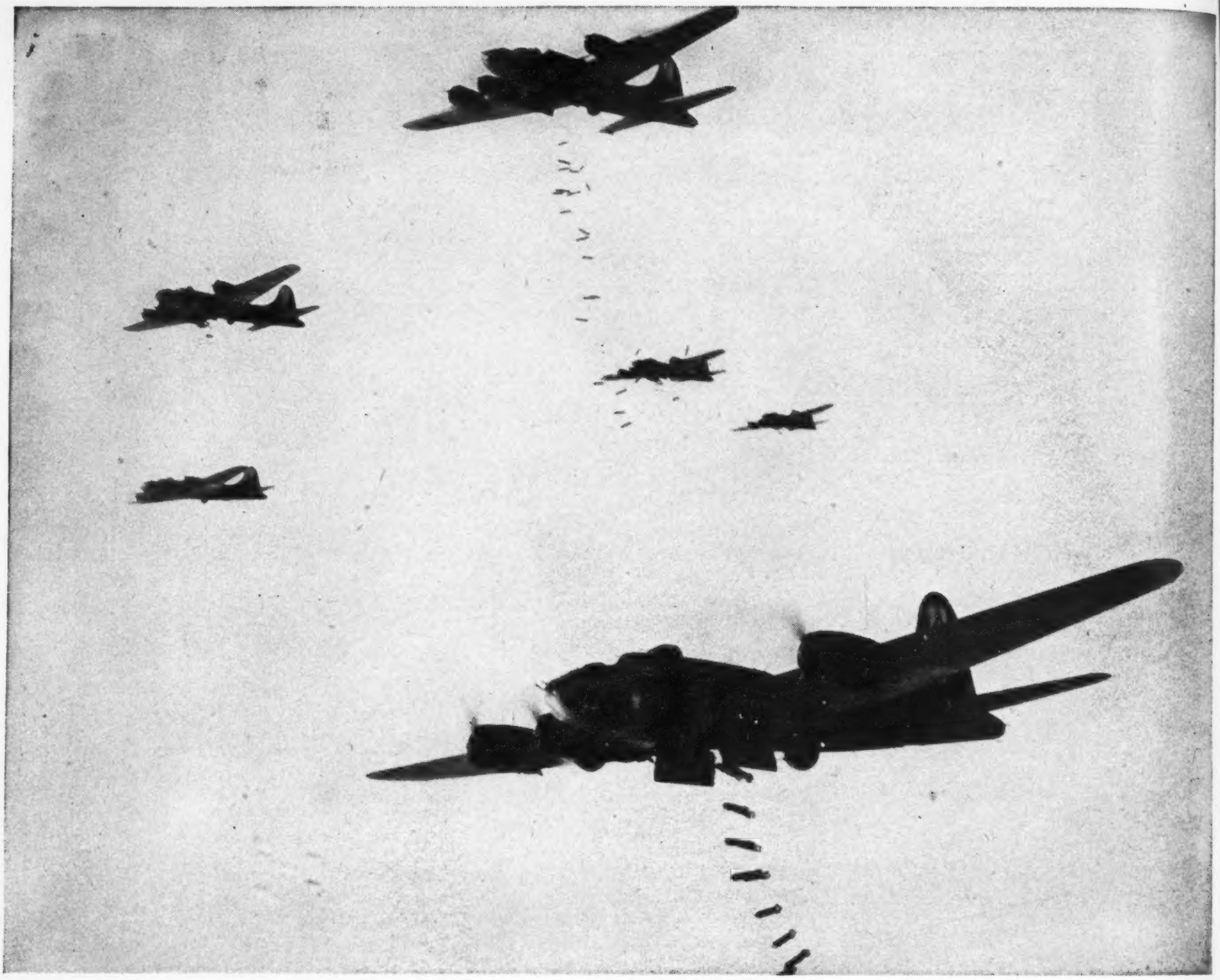

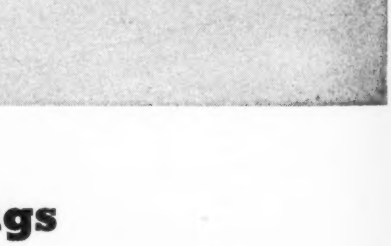

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Topics

TITANIUM PREDIPPING process increases life of zinc coatings fifty times, according to tests by Westinghouse. Utilized in a chemical "wipe" of disodium phosphate, a faint trace of titanium chemically prepares the surface for receiving a normal phosphate coating. The predip can be used for phosphating steel but the corrosion resistance is not always as marked.

SEVERAL HUNDRED successful flights of jet-propelled planes give indications that this accomplishment may prove to be one of the most important milestones in aviation history. First successful flights in this country were made in October 1942 based on an English design.

STARTING THE WAR with a .25-caliber rifle, the Japanese found it such a handicap in infantry fighting when confronted with the powerful American semiautomatic shoulder rifle, M1, that in mid-war they were forced to change to a .303-caliber. This rifle was used in the recent fighting at Tarawa.

IN ACCORDANCE WITH its policy of gradually releasing restricted materials which have a surplus, WPB has announced that automotive intake and exhaust valves may now be manufactured with the prewar quantity of chromium and nickel. Also, restrictions on the sale of vanadium, tungsten and molybdenum have been removed.

NEW HOISTING DEVICE enables the Army Jeep virtually to pull itself up by its boot straps. Designed to enable the Jeep or other vehicle to extricate itself from deep mud or mire, the vertical winch has a minimum hauling power of 2000 pounds.

LEAD-COATED STEEL is doing a better job for certain applications than did copper or brass prior to their substitution by this alternative material. Such steel has been adopted by the General Electric Co. for making banding rings for rotors of some types of motors. The rotors are balanced by placing on these bands drops of solder which cling as well to the lead coat as to copper or brass. Also, the higher tensile strength of the steel enables a weight saving in the bands of 60 per cent and allows a greater radial space for the application of balancing solder.

SUPERSONIC WAVES test rubber tires for flaws by placing a tire in a water trough and slowly rotating the tire. The supersonic waves pass through the water and the tire. Picked up by a microphone, waves passing through solid rubber light a green lamp whereas a flaw breaks the continuity of the waves and causes the lighting of a red lamp.

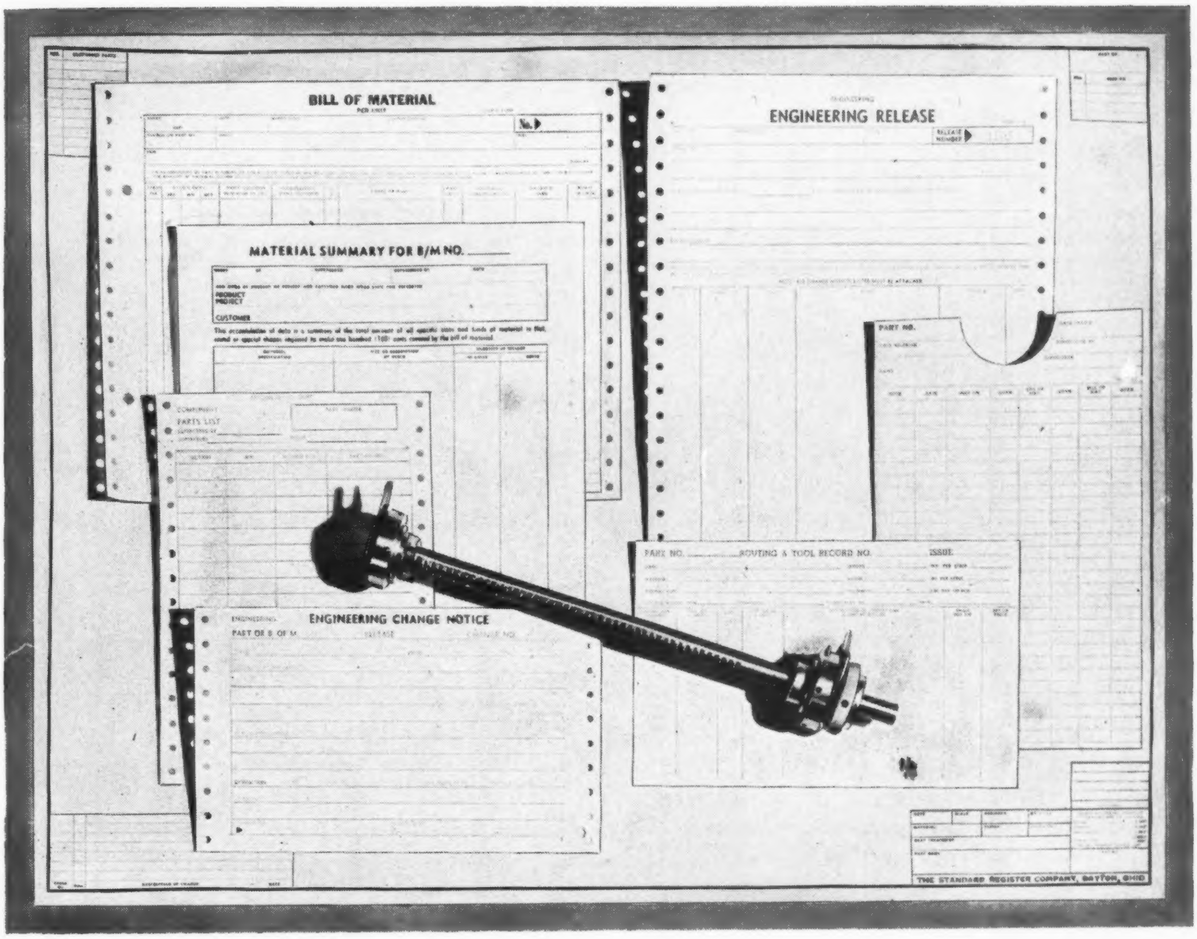
A RAID of 1000 four-motor bombers over Berlin consumes 800,000 gallons of gas on its mission. In terms of a passenger car averaging 15 miles per gallon and operating 12,000 miles a year, this amount of gasoline would supply sufficient fuel for 1000 years!

INDICATIVE of the advances in design and labor utilization, for every 100 workers required to build an attack bomber, a fast interceptor and a medium bomber in 1940, the figures now have been brought down to nine for the attack bomber, five for the interceptor and 10 for the medium bomber.

TOOL DIVISION of WPB has begun a selective survey of antifriction bearing users' requirements to develop a more realistic schedule for meeting the continuing pressure for military purposes. Indicative of the quantities of bearings used the New Departure division of General Motors produced more ball bearings during November and December than it made during the whole four years of World War I.

ELECTRONIC DEVICES controlled about 10 per cent of all electric energy generated in the United States during 1943. Much of this total was contributed by the light-metal and electrochemical industries employing electronic rectifiers for direct-current power.

INVISIBLE FLAWS in aluminum castings are spotted by an ultraviolet test now being used by General Electric. Castings are dipped into a special fluorescent preparation which penetrates cracks or other flaws. When exposed to ultraviolet radiation the defects are visible immediately.



Engineering a System for "Engineering"

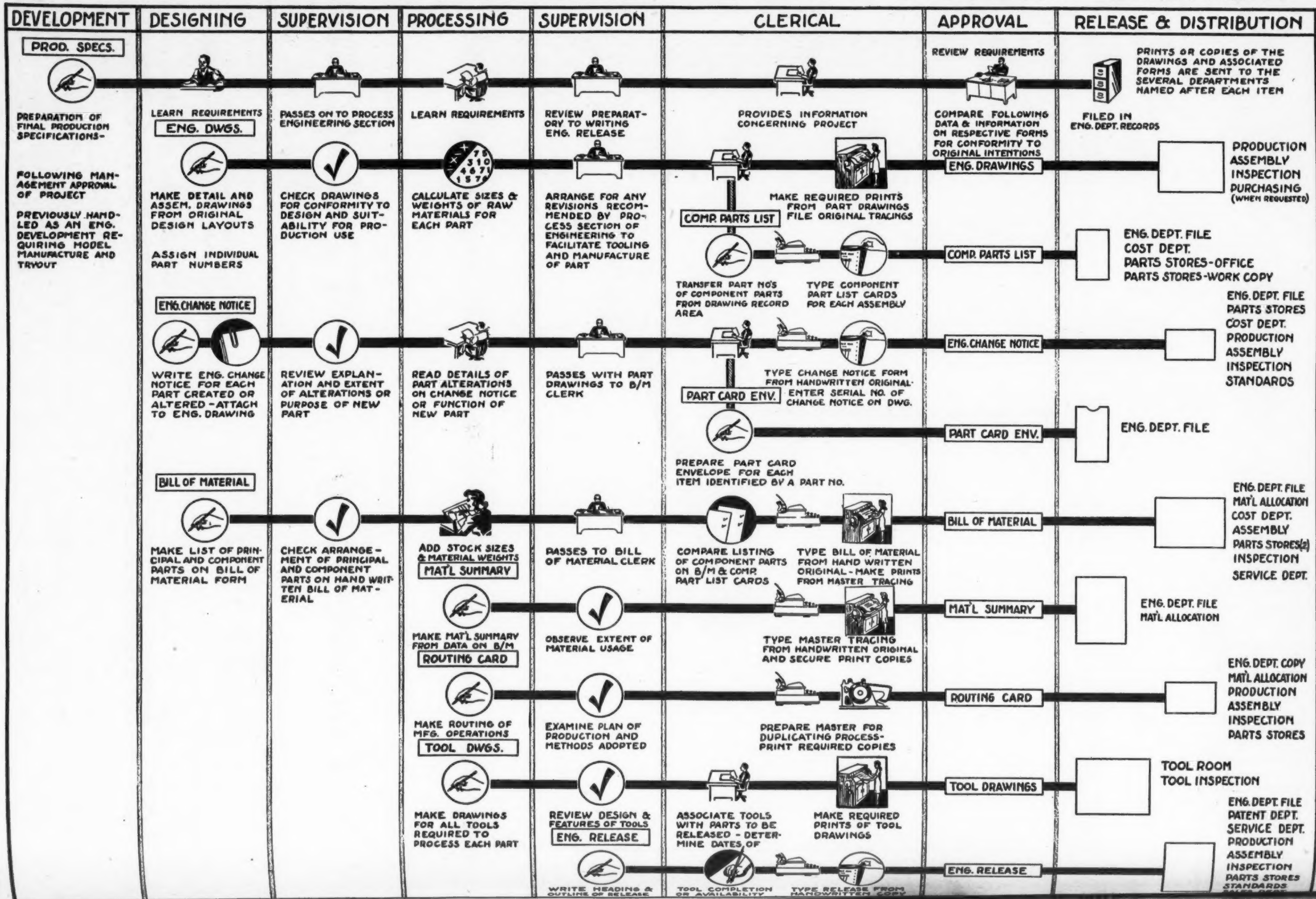
By **John T. Davidson**
Chief Engineer
The Standard Register Co.

TOO often the engineering department goes its own merry way, establishing part numbers, drawing numbers, engineering routines, and so forth, oblivious of the fact that other plant departments must use the part numbers or drawing numbers in their daily routines in production, stock control, service and field correspondence.

It is evident that any engineering department system should take into account these needs and that, to be effective, the system should be so automatic that persons with

Fig. 1—Above—These forms are used to transmit basic data, originating on the engineering drawing, to plant departments

FLOW CHART SHOWING ROUTINE AND FORM PREPARATION IN ENGINEERING DEPARTMENT



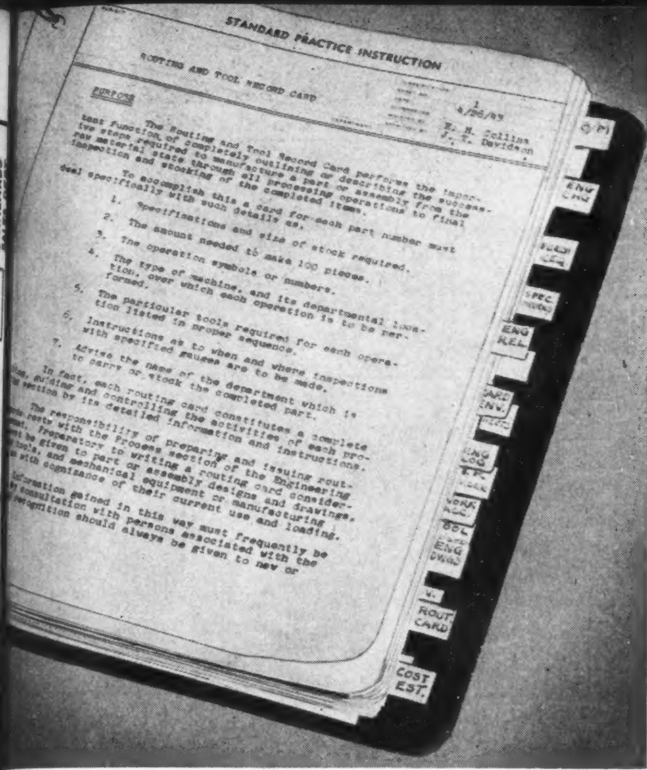


Fig. 2—Above—An instruction manual for each engineering department member deals with the purpose, function and preparation of departmental and interdepartmental forms. Routing is illustrated by flow charts

little or no experience can handle the necessary work efficiently with a short period of training, while in no case should employees in clerical or routine work be forced to make decisions. With these objectives in view, the basic rules and routine discussed in this article were established.

Each individual part or assembly must be assigned an individual designation consisting of a prefix symbol, indicating the type of mechanism for which the part was originally designed, and a numerical portion, which is never duplicated on any other part (example:FC-8756). Subassemblies and final assembly part numbers must have the letter "S" added as a suffix (example:FC-8767-S).

This designation serves both as drawing number and part number and is used in all records, making for uniformity throughout. The part retains this designation forever, even though the part is used in a mechanism for which it was not originally designed.

When changes are required in a part, which permit the altered piece to be used interchangeably in the mechanism with the former style, the part and its number continue to exist and the drawing remains alive and usable.

When Parts Become Obsolete

When changes are so extensive that the redesigned part cannot be used interchangeably with the preceding form which performed the same function in the mechanism, the superseded part is abandoned (if it has no continued use elsewhere) and its drawing is marked "obsolete". In any event a new drawing of the superseding part, identified by a new part number, is created to take the place of the obsoleted item in the application in question.

Fig. 3—Opposite page—Flow chart correlates engineering department activities

Engineering changes on parts which continue to be interchangeable with preceding forms, are indicated by a letter, A, B, C, etc., known as an issue letter. This letter has no significance other than to indicate the particular change, and does not become a portion of the drawing number or part number. Issue letters have a specific import, however, to associated plant departments.

The stock control department is interested in this issue letter during the transition period between the disposition of old stock and the procurement and placing in stock of new style parts, each type being identified and distinguished during this interval by the respective issue letters denoting the style. When the stock control department has disposed of the old style part and only the new style or later issue is available for disbursement the issue letter loses its significance for this department.

As a means of correcting the piecework rate to conform to the changed design the standards department is concerned with the issue letter. When production of the new style part is under way and prices are set, the issue letter ceases to be of consequence to this department.

To check and distinguish between former and new production costs of the changed part, as changes may increase or decrease costs, the cost department has use for the issue letter. Similarly, once the change is instituted in production and old-style parts are used up, the necessity for the issue letter as a distinguishing feature disappears.

The service department is interested in the issue letter when called upon to supply a repair or replacement part

ARE YOU SEEKING ways to unburden yourself of detail, free yourself for constructive endeavor? Then read this article, which tells how to organize an automatic system for the effective utilization of inexperienced personnel in the performance of "engineering's" many routine tasks

for any mechanism. The issue letter specifies the exact form of the part needed.

Close attention of the production department must be given to issue letters which appear on part orders during intervals when part changes are being effected, in order to complete open orders to the proper drawing specifications and handle associated part orders which may be involved in the evening-up-stock-process that frequently accompanies the handling of part changes. When all old-style parts have been made and used, however, the print from the latest part drawing replaces the print of previous issue, and the latter must be destroyed to prevent subsequent errors.

The inspection department, likewise, must pay close attention to issue letters in order properly to identify and inspect parts of both styles passing through the department during periods of conversion.

Every drawing must of course have the necessary dimensions to enable production of the part without reference to other drawings. This rule applies even though two parts differ so slightly that one may be made from the

FUNCTIONAL CHART SHOWING USE OF ENGINEERING DEPT. FORMS BY FACTORY AND ASSOCIATED DEPTS.

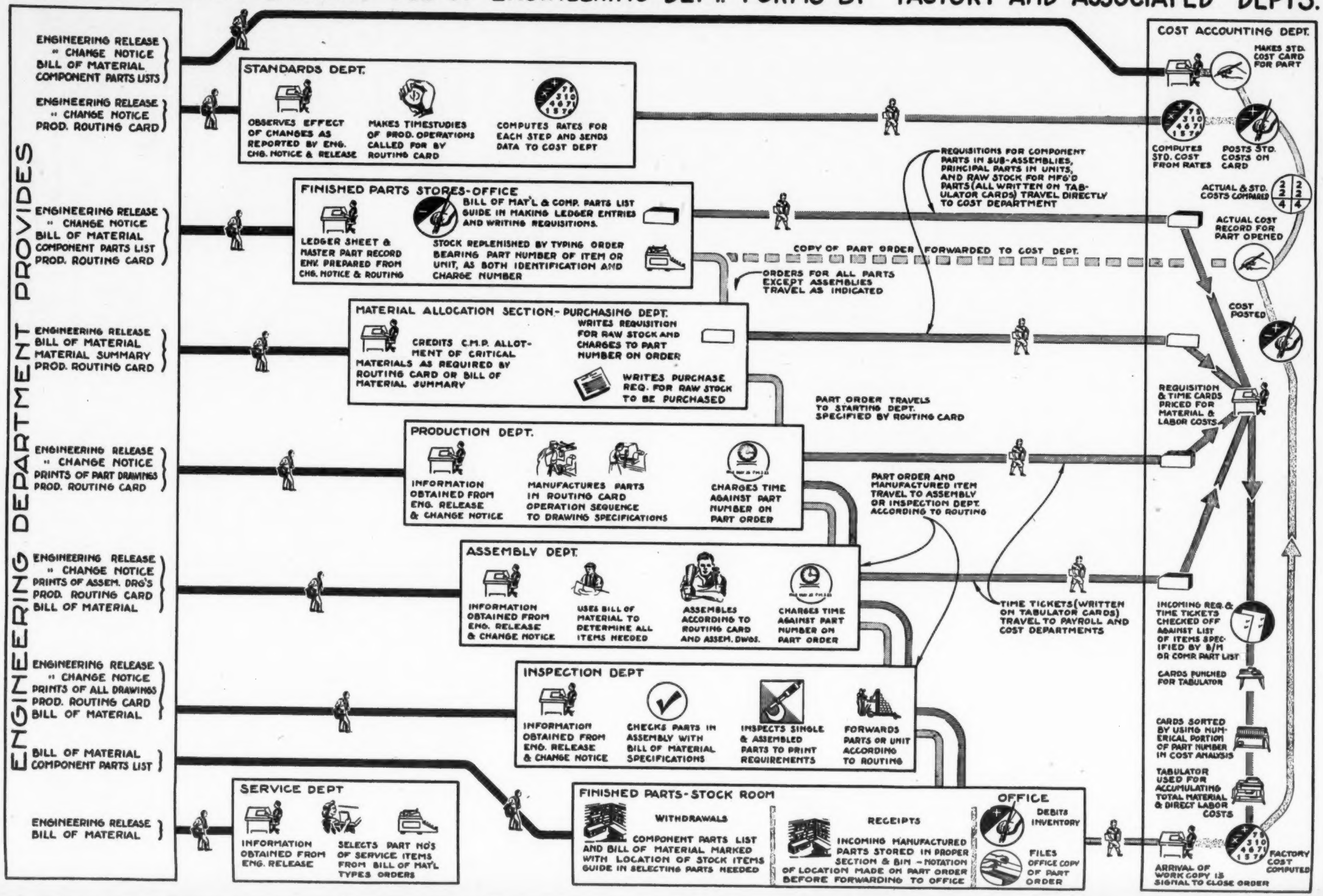


Fig. 4—Opposite Page—Chart shows how information furnished by the engineering department is utilized

other by an additional machining operation. It remains a function of the routing card for the individual part to outline the most practical and economical means of production.

Where a part considered as an assembly can pick up its component parts during the progress of the major piece through its manufacturing sequence, the part drawing, in addition to having all the necessary construction dimensions, has the component parts shown by broken lines in their assembled positions, properly designated by their respective part numbers. The part or drawing number of the assembly includes the "S" suffix. This scheme makes one drawing serve in many cases where two others, a detail drawing and an assembly drawing normally would be used.

This latter practice, a common routine in many engineering departments, causes the stock control department to issue separate orders for subassembly work which in many cases could be performed in one production sequence, along with the manufacture of the main part of the assembly.

The combination drawing supported by a routing card saves the writing of many production orders each year in our plant and eliminates the physical handling of parts in and out of stock in the course of producing such subassemblies. It is to be understood, of course, that some of the subassemblies that are put together cannot be handled in this manner.

Associated Forms and Records

Each new or changed drawing must have an Engineering Change Notice prepared for it. Each new or changed drawing must have a Routing Card, and in addition to these an assembled part must have a Component Parts List Card.

Each part has an engineering department master envelope card in which the entire history of the part is kept. The envelope contains the engineering department copies of the engineering change notices, production routing cards and component parts list cards, if the part is an assembly. The face of the card bears such information as the part number, part name, a list of the engineering change issue letters and data showing usage.

Each type of assembled mechanism or unit has a complete Bill of Material, which is a combination parts list and actual bill of material.

Parts listed on the bill of material preceded by item numbers can be drawn from stock and constitute items in the final assembled unit. To assist in determining material requirements under CMP, the bill of material also lists the component parts of each principal part, providing a complete analysis of all basic material needs. Those parts not having item numbers cannot be drawn from stock to be assembled into the completed unit.

Each bill of material has a summary sheet, correlating and totaling the various kinds and sizes of raw stock itemized in the bill of material, to assist in requisitioning the necessary raw materials. Each bill of material is identified by a consecutive number, and the rules pertaining to interchangeability of parts also apply to bills of material.

Every complete unit or mechanism carries a serial number consisting of the bill of material number followed by letter symbols representing the type of unit and a consecutive number based on the chronological sequence of production of that unit (example:714-ad-1080).

It is obvious, since all bills of material constitute a permanent record, that regardless of the age of any machine in the field it is possible through the proper interpretation of a serial number to locate the exact bill of material which originally supported the construction, and from this record determine any part number which was used and the particular issue in effect at the time of manufacture.

Special or experimental part numbers and bills of material have identifying numbers preceded by the prefix "X". Thus when special or experimental parts or units are to be placed in production as standard parts and equipment it is only necessary to remove the "X" prefix to make the drawings and bills of material available for production use.

Of the several departments in our organization which receive and use instructions and information from the engineering department only three, the inspection department and the production and assembly sections of the manufacturing department, regularly receive prints of part drawings. The engineering change notice, routing card, component parts list card, bill of material and bill of material summary therefore become the means of conveying their respective kinds of information to associated plant departments.

The task of informing each interested department of the work which has been done by the engineering department and of their individual responsibilities in carrying any project to completion is accomplished by using the engineering release, to which the supporting forms needed by any department are attached.

Every part print, change notice, bill of material, routing card or other form prepared by the engineering department must be accompanied by an engineering release stating the authority under which the work was done and what further duties must be performed to accomplish the objective. Its use eliminates verbal orders and instructions and as a permanent record it constitutes a necessary and valuable reference source of work accomplished.

Routine of Drawing and Form Preparation

The basic conceptions outlined in the preceding paragraphs influence the procedure of accomplishing the work involved in preparing drawings and associated forms in the engineering department. A definite effort has been made, however, to arrange a sequence of work which takes into consideration the function and importance of each type of data or information, and the time at which it can most conveniently be prepared in the program.

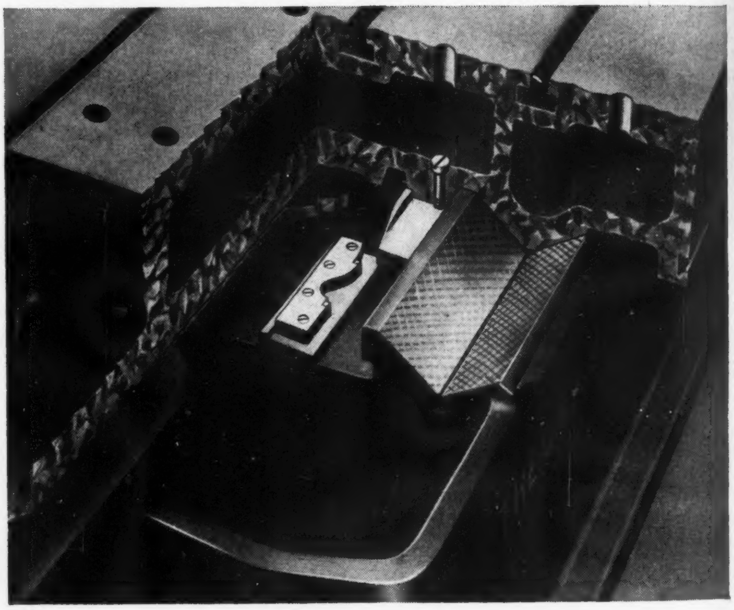
A graphic aid of considerable assistance in the original analysis of the objectives and means of accomplishment, as well as an illustration of the program to others, is the flow chart, *Fig*. 3. When augmented by symbols showing operations, objects, devices or participants its meaning is greatly clarified.

(*Concluded on Page* 246)

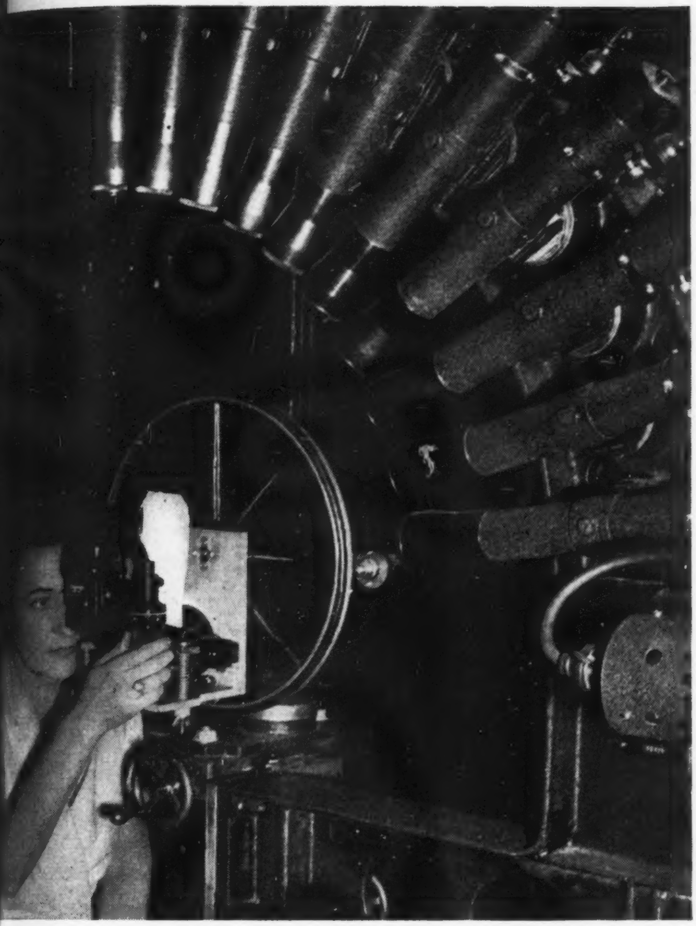
Scanning the field for IDEAS

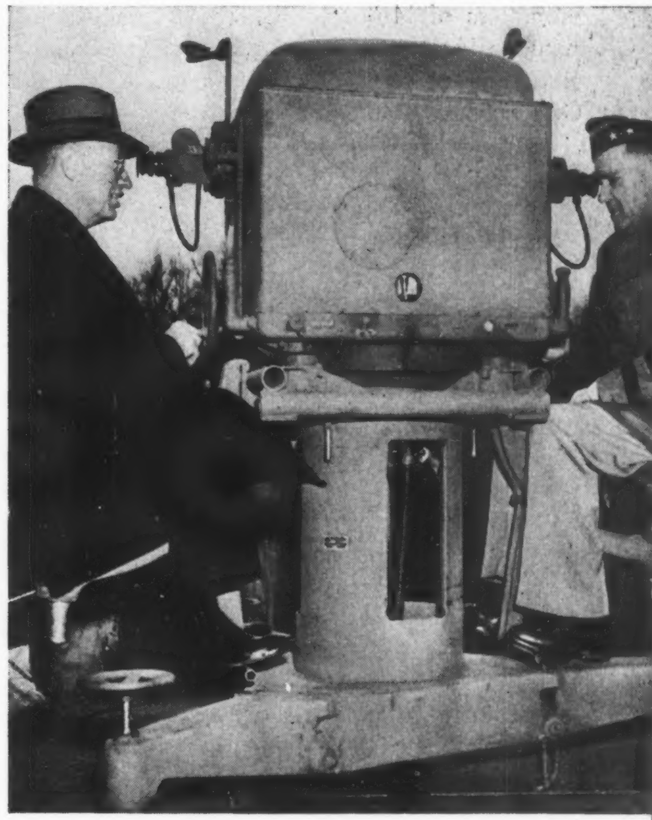
SAFETY limit switch which depends on its ingenious simplicity for foolproof operation utilizes cutting tools to absorb energy in event of overtravel. The high speeds at which machine parts such as planer tables now operate greatly increases the danger if the table runs off the bull gear. Usually this condition is caused by failure of some part of the control or of the reversing drive motor.

After studying spring-operated and hydraulic buffers, the G. A. Gray Co. developed under the direction of John M. Walter, Chief Engineer, the device illustrated at right in which the pressure on cutting tools is used as a braking means. These cutting tools are bolted to the bed and a cast iron block is fastened to the lower side of the table in such a way that the cutting action would not tend to lift the table. Taper of the block is such that cutting effort increases smoothly, the second tool starting its cut after the first is fully engaged. Cutting edges of tools are protected with plastic to prevent the possibility of injuring workmen while setting up or servicing the machine. Even though the device may not be brought into operation for many years, it remains a positive protection against dangers of overtravel.



Heremetically sealed plastic packages for protecting machine parts in shipment and storage have been developed by the Dow Chemical Co. Shown at left, the protective covering is an ethylcellulose base plastic applied by a simple hot dip at 350 to 375 degrees Fahr., setting into a tough skin-tight coat to protect the part from corrosion and dirt. Obviating hand wrapping of greased parts, the method also simplifies putting part into service. Coating is easily stripped off as shown in the illustration without need for degreasing or other cleaning operations.





Calibration of sextant is facilitated by the use of the special collimator shown above. Designed by Bendix Aviation Corp., each of the radially mounted tubes contains an illuminated star-like reticle to permit accurate calibration by permitting precise fixes on the tiny simulated stars at angles ranging from zero to 90 degrees elevation.

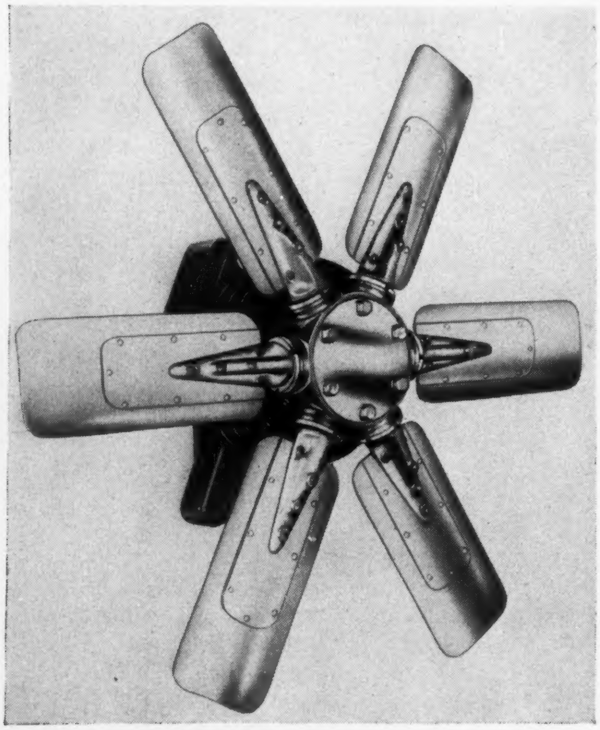
Variable-speed transmissions direct, with uncanny precision and by remote control, the fire of the antiaircraft gun shown at right. The control unit known as the M9 gun director, employs two Graham transmissions, one to rotate the tracker in azimuth and the other to control elevation. Each movement employs an operator as in top right illustration. Two men are stationed at the gun to take over manual control if necessary. Besides the tracker the director, built by Western Electric Co., consists of an electrical computer and a range finder, each a separate unit coordinated with the other to create an "electric brain". It tracks the plane, au-

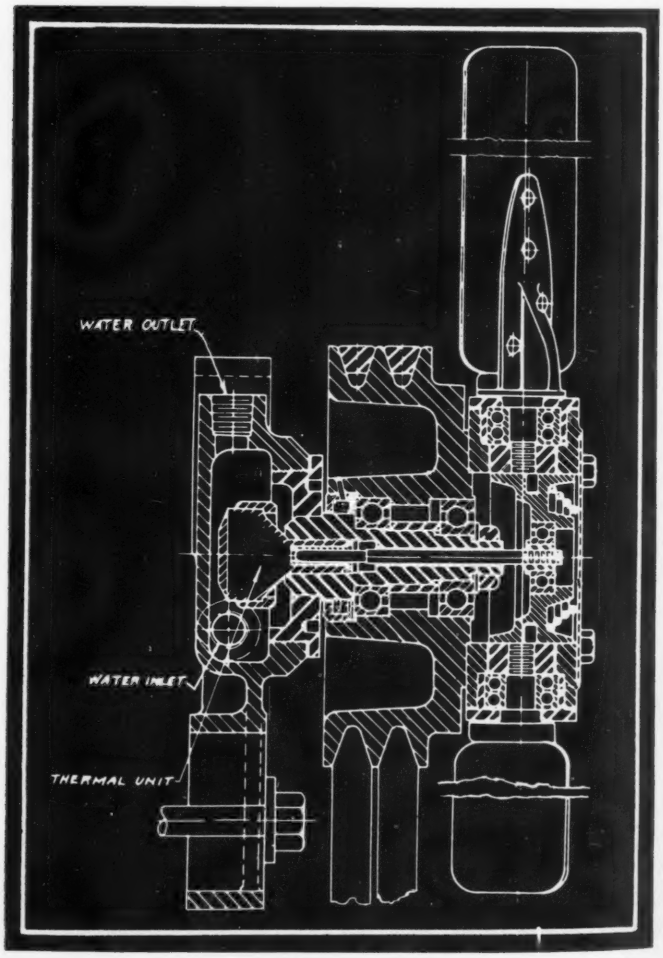
tomatically calculates the lead of the guns to suit the individual conditions, follows the flight and aims electrically.

Two-speed winch drum, below, having diameters of 14½ and 12 inches, has four riser sections located between the two flanges to facilitate the rapid winding of thin, tough steel wire. Of hollow cast and heavily ribbed design the Meehanite drum, produced by the Cooper-Bessemer Corp., is for Army use. This drum effected a reduction in weight of about ten pounds per drum and increased resistance to cutting and abrasive action of the thin wire as it speeds over the surfaces of the core.

Controllable pitch blade fan, below, is automatically responsive to temperature change. Developed by Kontrol-Fan Inc. for internal combustion engines, the fan controls engine cooling by utilizing a thermal element in the water coolant system. Thus, at overload, continuous capacity is raised by employing maximum cooling effect while, at low loads, efficiency is increased by allowing engine temperature to rise to best operating conditions. Also, while operating at low loads the energy required to drive the fan is negligible inasmuch as it runs at no pitch.

As shown in the drawing the thermostat is of the solid expansion type, connected by a rod to the center section of the fan hub. Change in temperature of the water causes expansion or contraction of the thermostat and a corresponding movement of the hub center. Each blade of the fan is rotated by this movement to control the pitch. Range of pitch is preadjusted by the rod length.





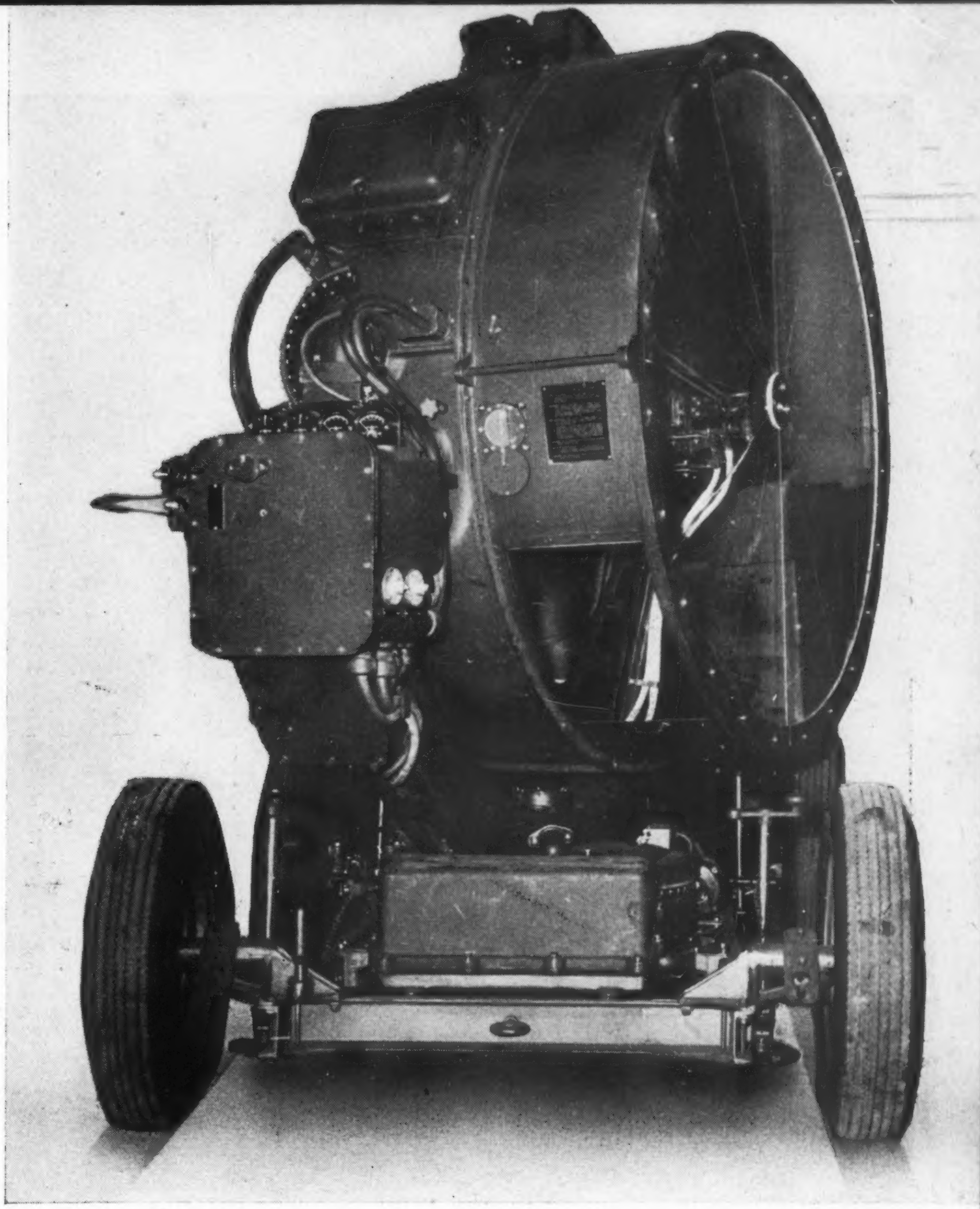


Fig. 1—Main structure of this 60-inch Army searchlight was redesigned to utilize stampings in place of aluminum castings and sheet

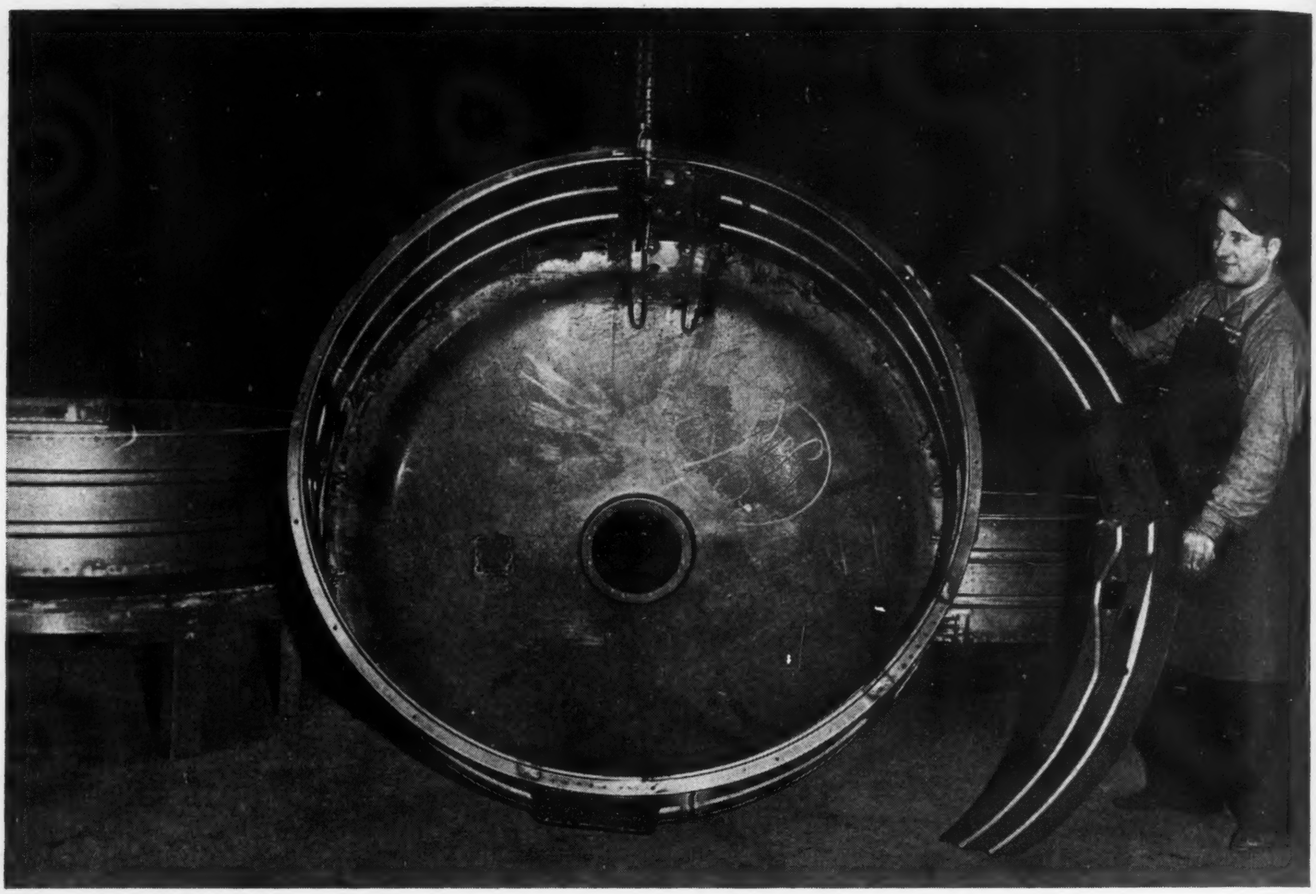
Redesigning To Utilize Stamping Process

Part I

By Colin Carmichael

WHEN Pearl Harbor put a virtual end to the manufacture of automobiles, household appliances, toys, and other mass-produced items, the extensive facilities of the stamping industry became immediately available for the production of parts for war. The simultaneous need for ordnance and aircraft items in tremendous quantities led to a partnership which has been mutually beneficial to the war program and to the advancement of the art of producing parts by stamping or pressing. Lessons learned in the process of redesigning numerous parts have opened up new possibilities to designers of all types of machines, offering an alternative to machined castings, forgings and bar stock for many parts. The successful performance of stamped parts in arduous war service should dispel any lingering doubts that such parts lack the necessary strength and durability as compared with forgings or castings having greater weight and bulk.

Redesigns of war equipment to utilize stampings range from the



giant Army searchlight, *Fig.* 1, to such small components as the hollow spindle for .50 caliber ammunition chest shown in *Fig.* 3. Primarily introduced as a measure for conserving vital materials and utilizing available equipment, wartime developments in stampings also have revealed savings in man-hours and costs which run into astounding figures when parts are produced by the million.

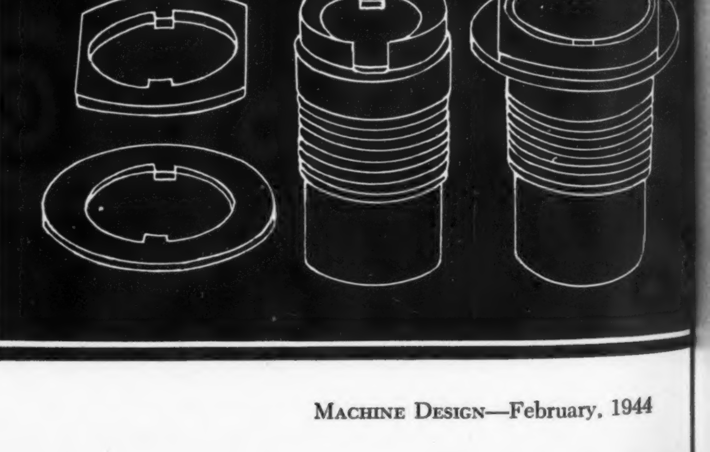
Although metal stamping is a process which came into being with the advent of mass production in industry, in its applications it is not necessarily limited to large volume production provided the parts are of such nature that the cost of dies is not excessive. In the course of this and the succeeding article some of the factors that affect die and production costs will be discussed, inasmuch as this question of cost is an important factor in determining the feasibility of applying the stamping process to the fabrication of machine parts.

Although many different stamping operations are performed, all such operations may be classified according to whether or not the metal thickness is appreciably changed. Thus, many parts are produced by a combination of shearing and bending, and have a uniform metal thickness substantially equal to that of the sheet or strip from which they were stamped. Those illustrated in the present article involve this type of work. More complex parts are produced from sheet metal by drawing or stretching, and call for a high degree of skill and experience in designing dies and selecting materials.

Simplest and least expensive form of stamping is the plain circular blank since the dies can be turned on a lathe and involve no hand work. Straight-sided blanks lend themselves to sectional die construction, also are relatively inexpensive. Following blanking, the simplest operations that are per-

Fig. 2—Drum assembly of searchlight is formed from simple parts which could be made in a one-hit operation and required no annealing procedures

Fig. 3—Small ordnance part, at right below, is an assembly of the three pieces shown alongside the part. Sheet metal and welded tubing substitute for bar stock



formed involve bending the metal. The chief requirement in designing the part is that the radius of any bends be sufficiently large, so that the material will not be stressed to the breaking point. Stock bent at right angles spreads at the bend and, if a straight edge is desired, small relief notches should be provided. Where bending in more than one plane is involved, complex stress conditions may be set up which, unless properly allowed for, may cause wrinkling or other defects.

Sheared metal, particularly in the heavier thicknesses, presents a rough surface and, where the punch enters the stock, material is usually slightly drawn down, resulting in burrs. By using punches which fit tightly in the dies, burrs can be held within .004-inch, which usually obviates the necessity for tumbling or hand-burring operations. Tumbling tends to fold burrs in rather than remove them, and the designer should consider how complete a burr removal is required when specifying.

Standard tolerance of punched parts is $\pm$.01-inch, but much closer tolerances can be held where required. However, on dimensions where no particular accuracy is required, this fact should be indicated. In general, manufacturers gage the location of holes, etc., from the base point of dimensions on the print. Such holes should therefore be dimensioned so that they will be properly located for assembly. Holes located from bends, especially those close to bends, will have to be punched after forming unless considerable leeway is permissible. For special tolerance or finish requirements it is well to consult a stamping manufacturer to see what can be done at reasonable expense. In establishing thickness tolerances it is necessary to be familiar with commercial tolerances of sheet material.

Tool costs are an important factor unless quantities are extremely large or parts rather small. Often parts can be designed to permit doubling up on certain operations, while in many instances parts can be designed to utilize the scrap centers, etc., of other parts. When parts are to be produced in large quantities high-grade tools will usually give a lower price per piece.

Because the vast majority of stampings are lighter than ⅜-inch, many considerably lighter, there has existed a feeling that stamped parts are useful only for decoration or for lightly stressed applications, and lack the strength and rigidity possessed by castings or forgings. By proper design, of course, it is possible to attain practically any degree of rigidity if stiffening members are located at strategic points. The searchlight, *Fig.* 1, is an outstanding example of a redesign where sheet steel stampings entirely replaced aluminum castings and aluminum sheet, resulting in approximately the same weight and stiffness.

Considerations which governed the redesign of this searchlight by engineers of the Murray Corp. are typical of other wartime conversion jobs, namely the need to conserve material and to utilize existing machinery. So far as the finished searchlight was concerned, it was only necessary that the steel parts be interchangeable with the original aluminum parts, thus making possible the repair of old searchlights with parts made by the new process. All requirements were met by 13-gage SAE 1020 steel sheet, which is approximately 3/32-inch thick, and which successfully replaced the original ⅜-inch cast sections.

In the case of the 65-inch drum assembly for the searchlight, *Fig.* 2, presses were available in the plant to make the entire drum as a single unit if desired. However, the necessity for interchangeability of parts and the desire for simplicity in dies and operations made it preferable to design the drum section as five stamped sections

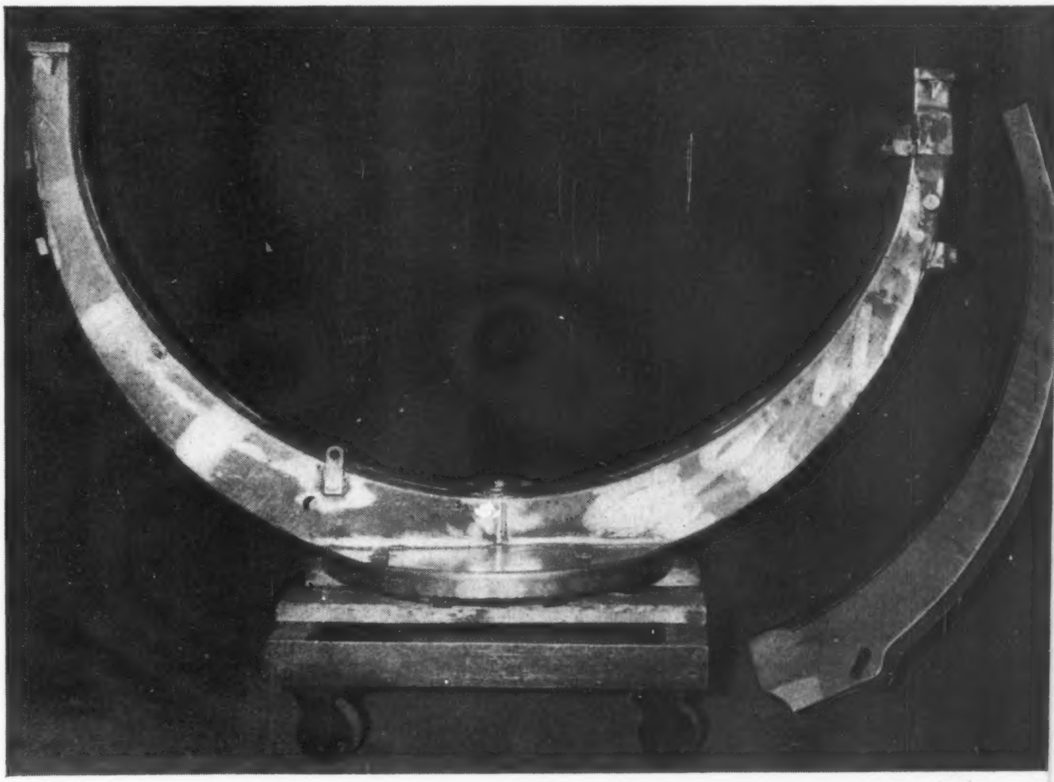


Fig. 4—Trunnion arms for searchlight are formed from U-shaped stampings, extreme right, welded together to form a rectangular box-section

—a back, three side pieces and a reinforcement strip. For ease in welding, the back section should have been stamped with flanged edges but as these would have detracted from appearance they were omitted and a special welding tool employed to reach inside the overlap.

Trunnion arms, *Fig.* 4, were fabricated from stampings formed in U-shaped sections welded together to form a box section and welded to the turntable top. The base housing was sheet steel. Ribs welded at all vital spots on the steel surfaces were the principal means of preventing distortion as the searchlight drum was rotated. This is an important consideration wherever castings of relatively thick section are replaced by thin sheet metal.

Because it was desired to make each piece in a one-hit operation, in dies of simplest possible design, no less than forty-two separate pieces were redesigned, including all parts for the drum, turntable and control boxes. Slight changes in corner radii of the control boxes were permitted to allow these to be made in a one-hit operation.

As a result of the redesign, 700 pounds of aluminum were saved on each searchlight and the production capacity of 30 boring mills released for other essential work. The presses used to produce the stampings had been making automobile parts and otherwise would have been idle. Because of the simplicity of the dies and the avoidance of deep-drawing operations, any need for annealing was eliminated. Unit cost, including dies, etc., was approximately the same as it was with the use of cast aluminum.

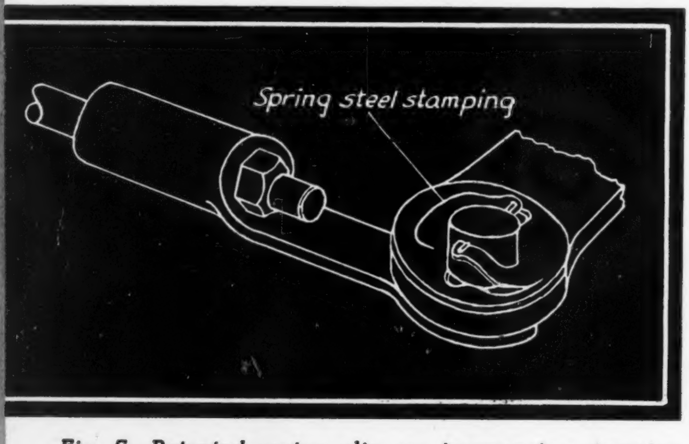


Fig. 5—Patented spring clip, an inexpensive stamping, replaces threaded connection using two locknuts

Another example of the conservation of material and machine-hours, on a different scale, is the ordnance part shown in *Fig.* 3. Originally this hollow spindle was machined from bar stock weighing one pound. Machining time was two minutes and the cost of the part twenty-five cents. As redesigned the part is assembled from the three elements shown at left of the figure, consisting of two stamped washers and a section of welded tubing. Assembly is done in a press, the three units being held together by upsetting the chamfer at the top of the tube. The gross weight of the stock in this case is only one-third of a pound, machining time is one minute and the cost of each piece eleven cents. This part was developed by Johnson Metal Products Co. and Cleveland Ordnance.

While many stampings are produced from low-carbon steel, because of its ductility, spring steel stock is used for parts where resilience is needed. An example is shown in *Fig.* 5. Formerly the pin on this coupling was threaded and two locknuts used to hold it in place. In the new design the unthreaded pin is secured by the spring steel stamping shown. Thousands of man-hours, which would have been required for threading and assembly, are saved in this one application, while the cost of the stamping is a mere fraction of that of the nuts.

Small gears are being produced today by stamping, coining and shaving, with circumferential tolerances under .002-inch and mirror-like finish in teeth and bearing surface. No machine-tool operations are required and when the gears are produced in quantities the costs are considerably lower than if gear cutters had been used.

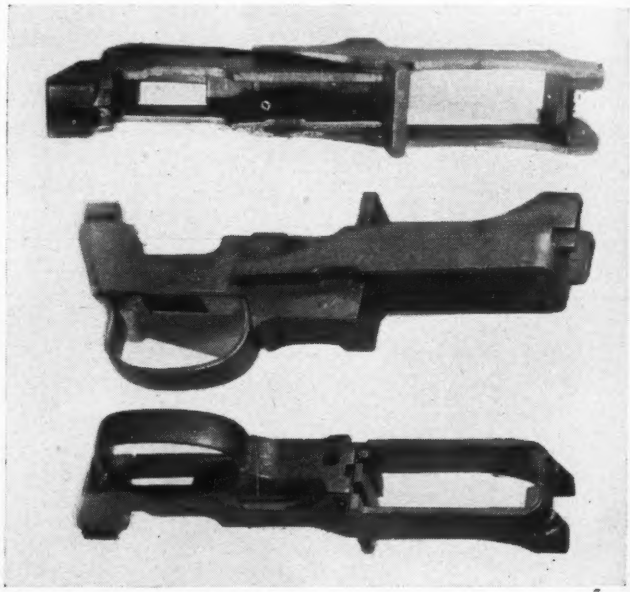


Fig. 6—Trigger housing for the .30-caliber carbine is a composite stamping assembled from 14 separate parts welded and copper-brazed

One of the spectacular illustrations of what can be accomplished with stampings is the redesign of the carbine trigger housing shown in *Fig.* 6. Stamping engineers studied the original housings, which were machined from castings or forgings, and broke the design down into 14 plane surfaces which could be stamped and formed on presses. The pieces were assembled by projection welding and copper brazing, with a final machine finishing on only a few surfaces. Tolerances were held to approximately the same values as before and the completed housing was interchangeable with the original. On the basis of a production run of over three million, the relative costs were approximately as follows: Forged, $5.00, cast $4.00, stamped $2.50.

A subsequent article will be concerned with stampings which involve severe deformation such as drawing, and will include a discussion of suitable materials. Further examples of notable stamping designs will be illustrated and discussed.

Machine Design is pleased to acknowledge the cooperation of the following organizations in the preparation of this article: Cleveland Ordnance; The Commercial Shearing & Stamping Co.; The Murray Corp. of America (*Figs.* 1, 2 & 4); Pressed Steel Tank Co.; The Reliable Spring & Wire Forms Co. (*Fig.* 5); and Worcester Pressed Steel Co.

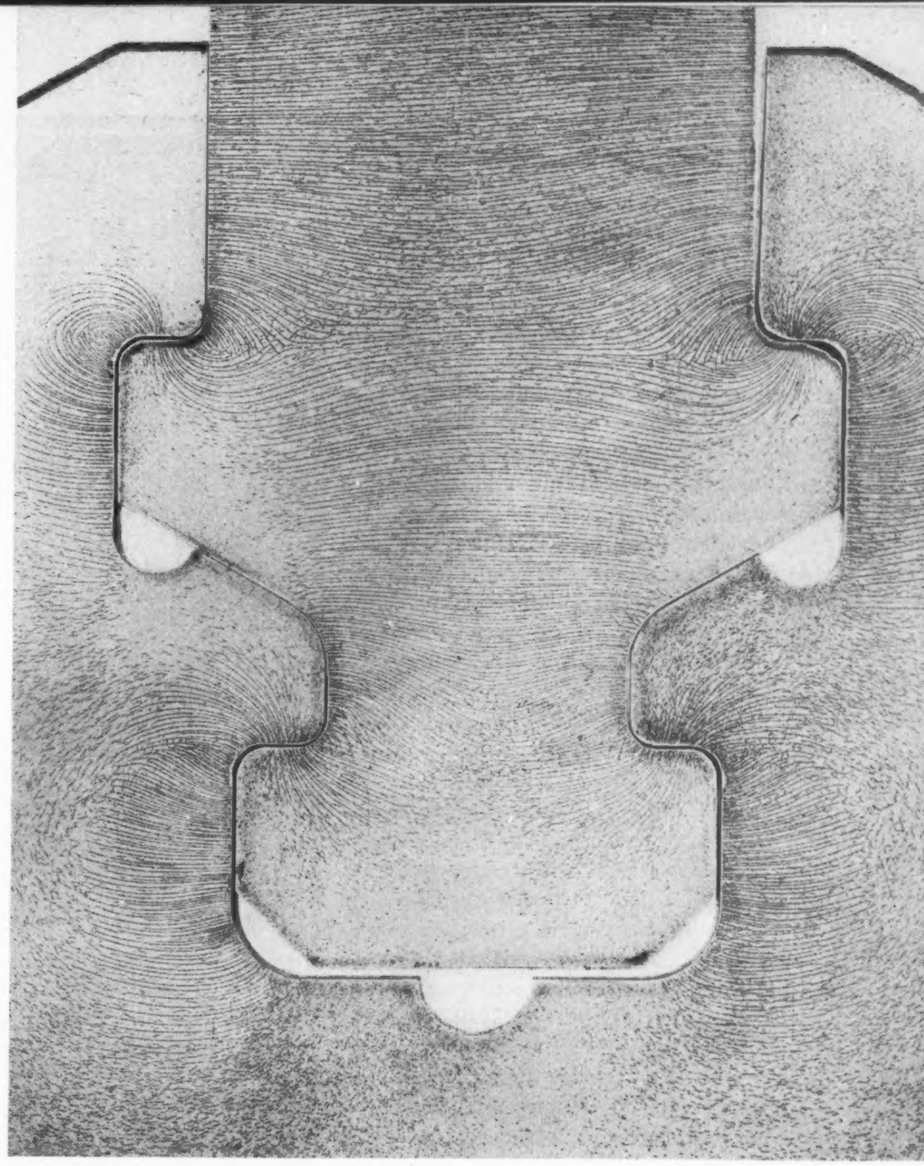


Fig. 1—Pattern of cracks in brittle lacquer coating indicates direction of principal tensile stress, which is normal to the lines

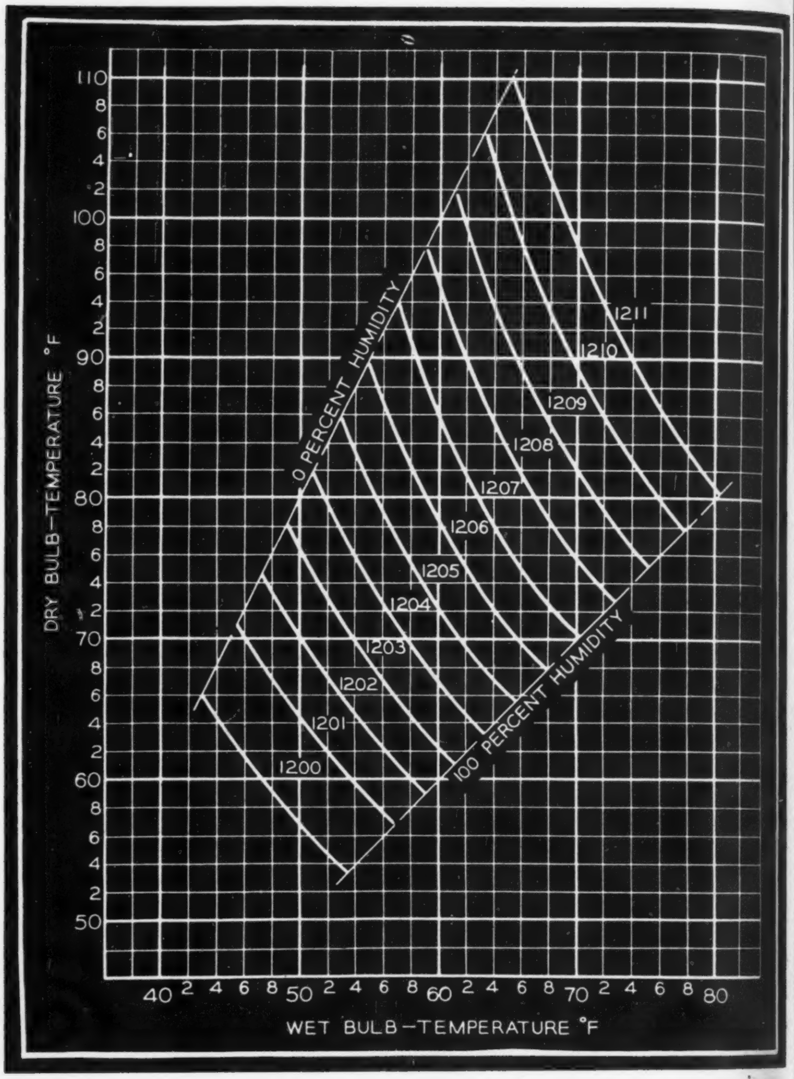
How Brittle Lacquer Strain Analysis Aids Design

By M. Hetenyi and W. E. Young
Westinghouse Research Laboratories

STRESS CONCENTRATIONS at the surface of machine parts are responsible for most structural failures, hence the measurement of surface strain in loaded parts furnishes valuable clues to the weak spots. In the accompanying article the use of brittle coatings for this purpose is discussed and some noteworthy applications of the method in design are described and illustrated

PROBABLY the first brittle coating used in stress determination was mill scale, the thin iron oxide layer which forms on hot-rolled steel stock. It has been known for a long time that mill scale will crack and flake when strains in the underlying steel become excessive, and this knowledge often has been utilized by engineers in locating highly stressed regions or in establishing an accidental overloading of mild steel structural parts. However, mill scale, on account of wide variations in its thickness and consequently in its sensitivity, never could be considered a dependable indicator and in its place a coat of whitewash which became brittle upon drying and served the same purpose often was used. Both mill scale and whitewash had the serious limitation that they indicated only strains of the order of one per cent or more, which occur in commercial steels only if the material has passed far beyond its yield point. These two coatings could, therefore, be classified

Fig. 2—Chart shows how to select Stresscoat lacquer for existing temperature and humidity. Lacquers are numbered and when properly chosen will first crack at .0005 to .001-inch per inch strain



not so much as strain but rather as damage indicators, which probably explains why they never found extensive application in the analysis of machine parts.

These experiences naturally prompted the idea of trying to find a coating material which would indicate strain values well within the elastic limit of steels. Experimental work in this direction was reported in Germany in 1932. Though the coating appeared to be dependable in locating stress maxima in various machine parts, its application was cumbersome and its cracking sensitivity could not be established definitely in terms of minimum strain.

While the latest available German publications still do not seem to show any improvement in the quality of their brittle lacquers, a superior coating material has been developed in this country and marketed under the trade name "Stresscoat". Since at present this is the only material developed and commercially available for stress analysis work, its tradename is used generally in referring to the brittle lacquer method itself.

Before describing the technique of this method it might be well to discuss briefly the requisites of an ideal coating material for this type of work. As stated above, the proper lacquer should show indications of strain well within the elastic range of steels. Also its strain sensitivity, that is, the minimum strain causing cracks in the lacquer, should have a definite value establishable numerically in each application. It also is necessary that the cracking sensitivity of the coating be fairly independent of its thickness, because it would be impossible to produce a coating of completely uniform thickness over the surface of complicated machine parts. To these chief requirements it may be added that cracks once developed in the lacquer should stay open in order to make observation possible, that application and removal of the coating should be simple and that it should dry to brittleness in a reasonable length of time at room temperatures.

All these requirements are reasonably well satisfied by the lacquer previously mentioned, its only undesirable property being extreme sensitivity to temperature and humidity conditions. In order to al-

Fig. 3—Testing the cracking sensitivity of a brittle lacquer by means of a calibration bar deflected as a cantilever

leviate this, with every experimental kit a set of 12 lacquers is supplied from which a suitable coating material can be chosen for any given condition. Selection of the right grade is based on temperature and humidity measurements in the room where the test is to be conducted, using the chart shown in *Fig.* 2. When chosen in this manner the lacquer

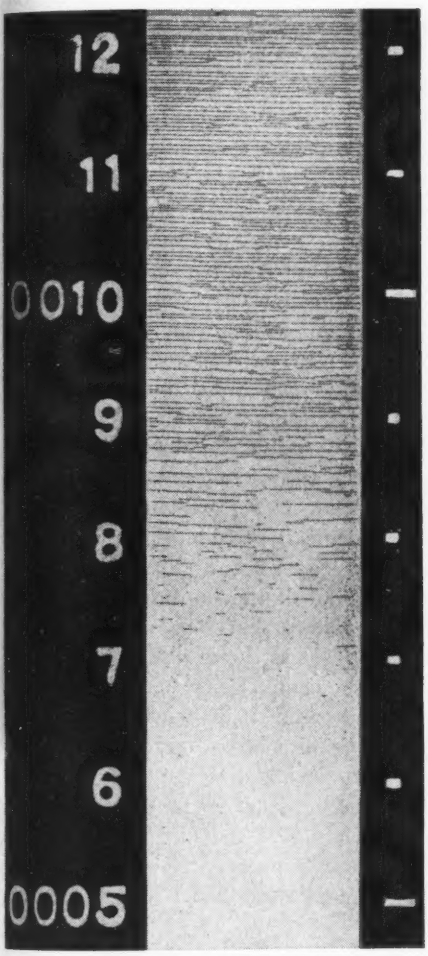
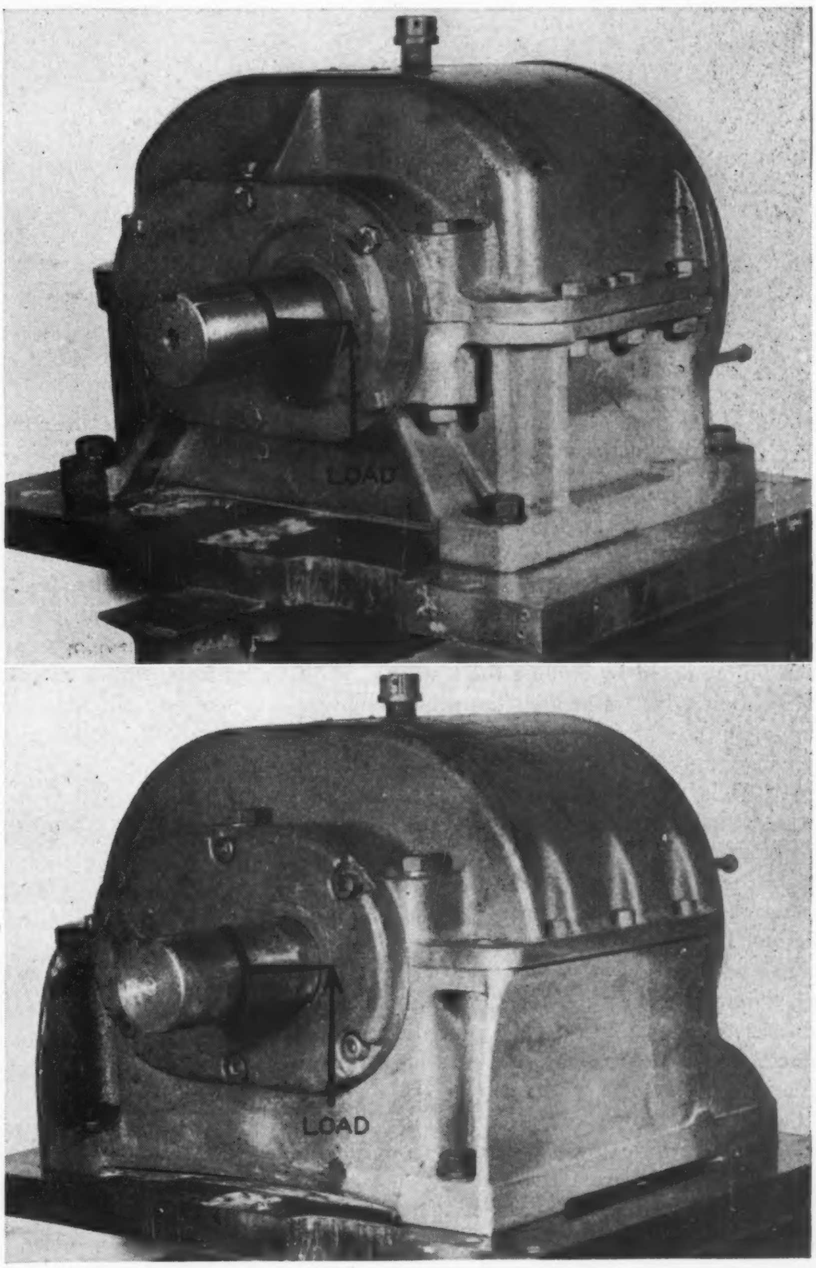


Fig. 4—Calibration bar in strain scale shows that for this case a minimum strain of about .00072-inch per inch was necessary to start cracks in the lacquer

will crack first when the strain in the test piece reaches a value somewhere between .0005 and .001-inch per inch, which is within the elastic limit for all commercial metals. The cracking sensitivity also can be determined exactly in each particular case by means of calibration bars which are coated with the same lacquer as the test piece and are kept close to it during the entire drying and testing period. At the time of the test these calibration bars are deflected in a cantilever fashion as shown in *Fig.* 3, producing a linearly increasing bending stress distribution from the tip of the bar to its clamped base. Then by putting the bar into the strain scale provided with the equipment, it is possible to establish exactly the minimum strain value necessary to originate cracks in that particular lacquer. In the case of *Fig.* 4 this minimum strain value was found to be .00072-inch per inch which, when multiplied by the modulus of elasticity of the material, gives the equivalent stress. For steel this would be a stress of $.00072 \times 30{,}000{,}000 = 21600$ pounds per square inch.

Once the sensitivity of the lacquer has been determined in the foregoing manner it is possible to proceed with the testing of the specimen. Loading has to be applied gradually while watching for the appearance of the first crack in the piece. The point where it appears will be the most highly stressed place in the test piece and the value of the stress, at that particular value of the loading, will be the same as that obtained from the calibration bar. With data on the appearance of the first cracks recorded, the loading can be increased while at each increment the corresponding growth of the cracks is noted. Although in this manner the stress distribution can be determined over a considerable area of the most highly stressed parts of the testpiece, on the other hand there is no direct way

Fig. 5—Brittle lacquer method was used to compare the stress distribution in the most highly loaded (front) corner of these two gearmotor housings



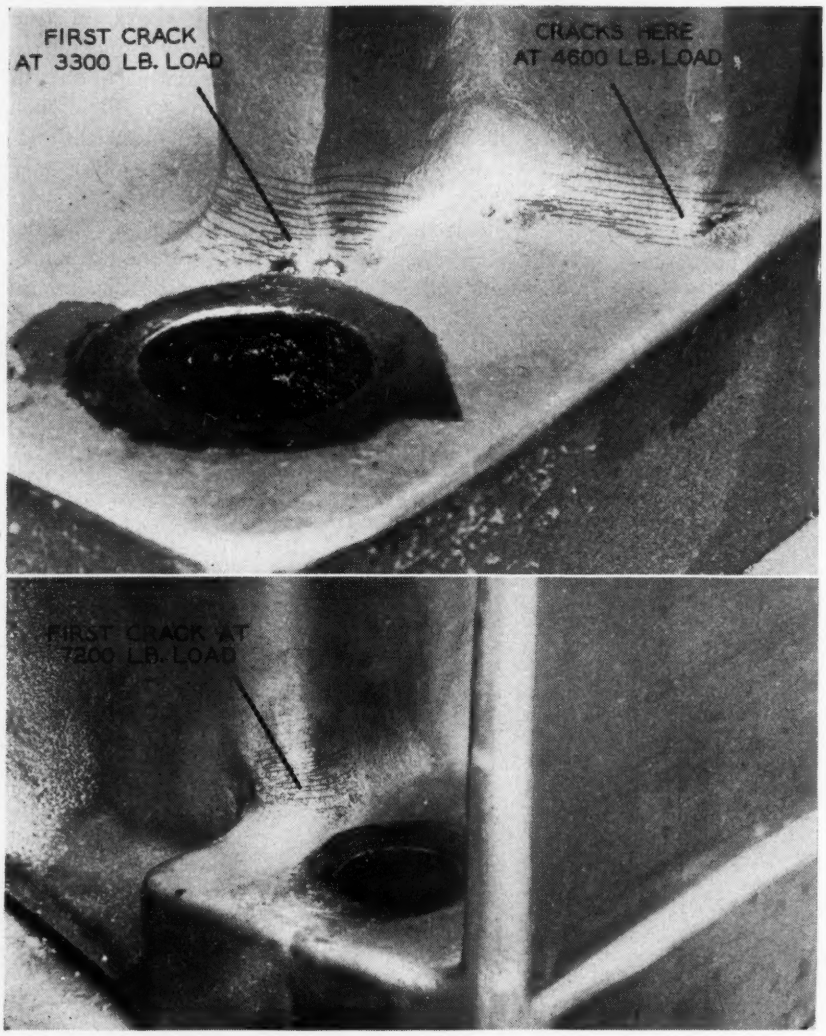


Fig. 6—Ratio of loads causing first cracks indicates comparative strength of footings in two gearmotor housing designs

to derive stress values from a fully developed crack pattern whose history of growth has not been recorded. The only conclusion obtainable from a full pattern is that its lines will be normal at every point to the direction of the maximum tensile stresses, which is useful information in many problems. If a picture of such a full pattern is desired, its development can be promoted by chilling the testpiece, while under load, with a stream of cold air. In this manner the principal stress lines can be unfolded also in regions where the strains caused by the loading were originally not great enough to cause cracking of the lacquer.

While chilling of the piece can be helpful in obtaining a full crack pattern, it has to be emphasized that in the main part of the test, when the place and intensity of the maximum stress in the piece is established, the testpiece as well as the calibration bars have to be kept at a constant temperature (± 1 degree Fahr.). The actual value of the temperature is not essential as long as it is within room temperature range, since in any case the proper coating material is selected from the chart in *Fig.* 2. The level of the temperature, however, must be kept constant within close limits during testing as well as the preceding drying period (12-18 hours) as a fluctuation of a few degrees can seriously affect the numerical accuracy of the method. Good results can be obtained only in an air-conditioned, or at least in a well insulated, room and thus the method is limited to the laboratory and could not be used quantitatively in the shops or in the field.

First cracks are rather inconspicuous as they appear in the lacquer and it needs considerable practice to detect them as soon as they are formed. Before application of the lacquer the surface of the testpiece is usually coated with an aluminum pigmented undercoating, the function of which is to provide a bright but glare-free background and thus facilitate observation of the cracks which even then show up distinctly only under oblique lighting. Such a procedure can be considered satisfactory for inspection purposes, but if a good photographic record is required of the crack pattern it must be etched with a red dye developed for this purpose. The pictures in this article were obtained from such etched specimens. Once a lacquer coating is etched it loses its extreme brittleness and becomes unsuitable for further tests.

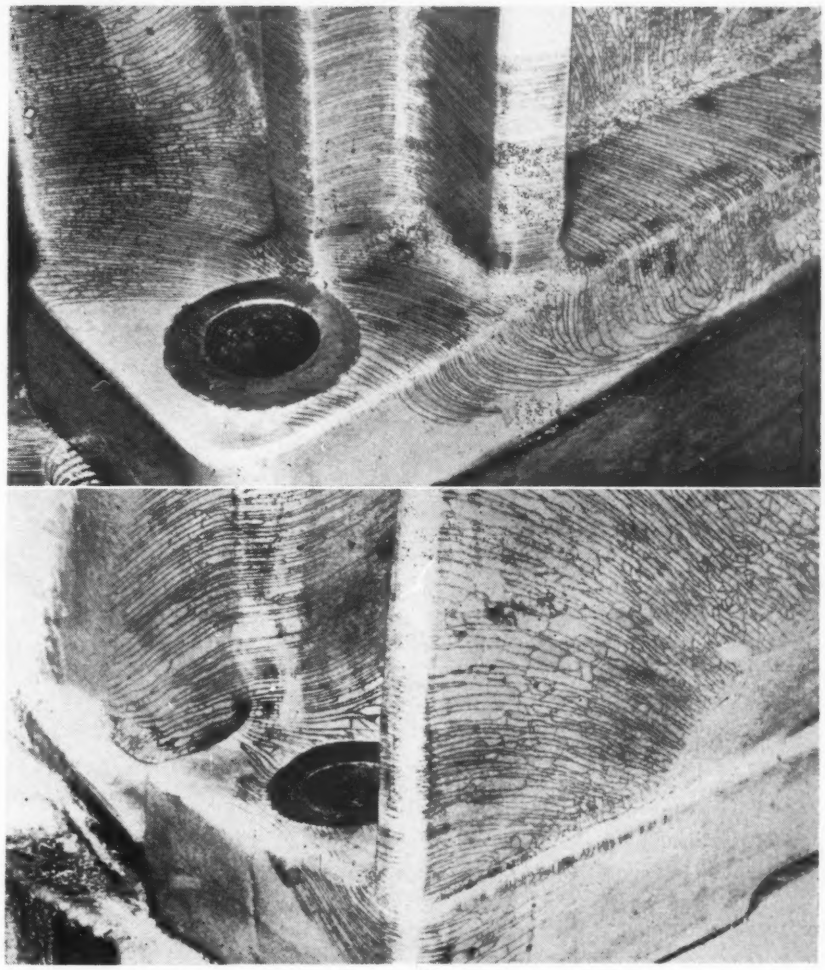
Comparing Alternative Designs

Used by the authors in the stress analysis of a great variety of machine parts, the brittle lacquer method has been found to be an extremely useful tool. One application was to determine the comparative strength of two gearmotor housings of an old and a new design, shown in the upper and lower pictures respectively in *Fig.* 5. In the older design some service failures were observed through the most highly loaded, front corner foot of the housings, so that the design had to be changed. The question now was how much increase of strength could be expected with the newer design. In testing these housings the cast iron surface had to be smoothened somewhat over the area under investigation in order to obtain a more even coating of the lacquer, but otherwise the test procedure was the same as that already described.

Method Shows Strength Ratio

Shown in *Fig.* 6 are the first cracks as they appeared at the most highly stressed points in the two footings. It is seen that the first crack appeared in the old design at a load of 3300 pounds while it required 7200 pounds in the newer design to start cracks in the lacquer. Since the cracking sensitivity of the lacquer, as determined by calibration, was the same in both cases the ratio of these loads will be the same as that of the maximum strain values in the two designs, which indicates that the new design is more than twice as strong as the old one. In order to check the results, after removal of the lacquer electric strain gages were applied to those points where stress maxima were indicated by the brittle coatings. Re-

Fig. 7—*Fully developed crack patterns, obtained by chilling, show the comparative stress distribution in the footings of the two gearmotor housings*



sults of these strain measurements were found to agree closely with those obtained by the Stresscoat method. At the conclusion of the tests both housings were loaded up to fracture and the ultimate loads found for the two designs also corroborated the results of the preceding stress analysis. As supplementary information on the nature of the stress fields in the two footings, *Fig.* 7 shows the full crack patterns obtained by chilling the coatings while the specimens were under load.

Another application of the method is shown in *Fig.* 8. These generator brackets, each about 6 inches in diameter, were bolted down along their base rings, to the left in the figure, and loaded in bending like cantilevers. The interesting and unexpected feature of this test was that the first crack made its appearance

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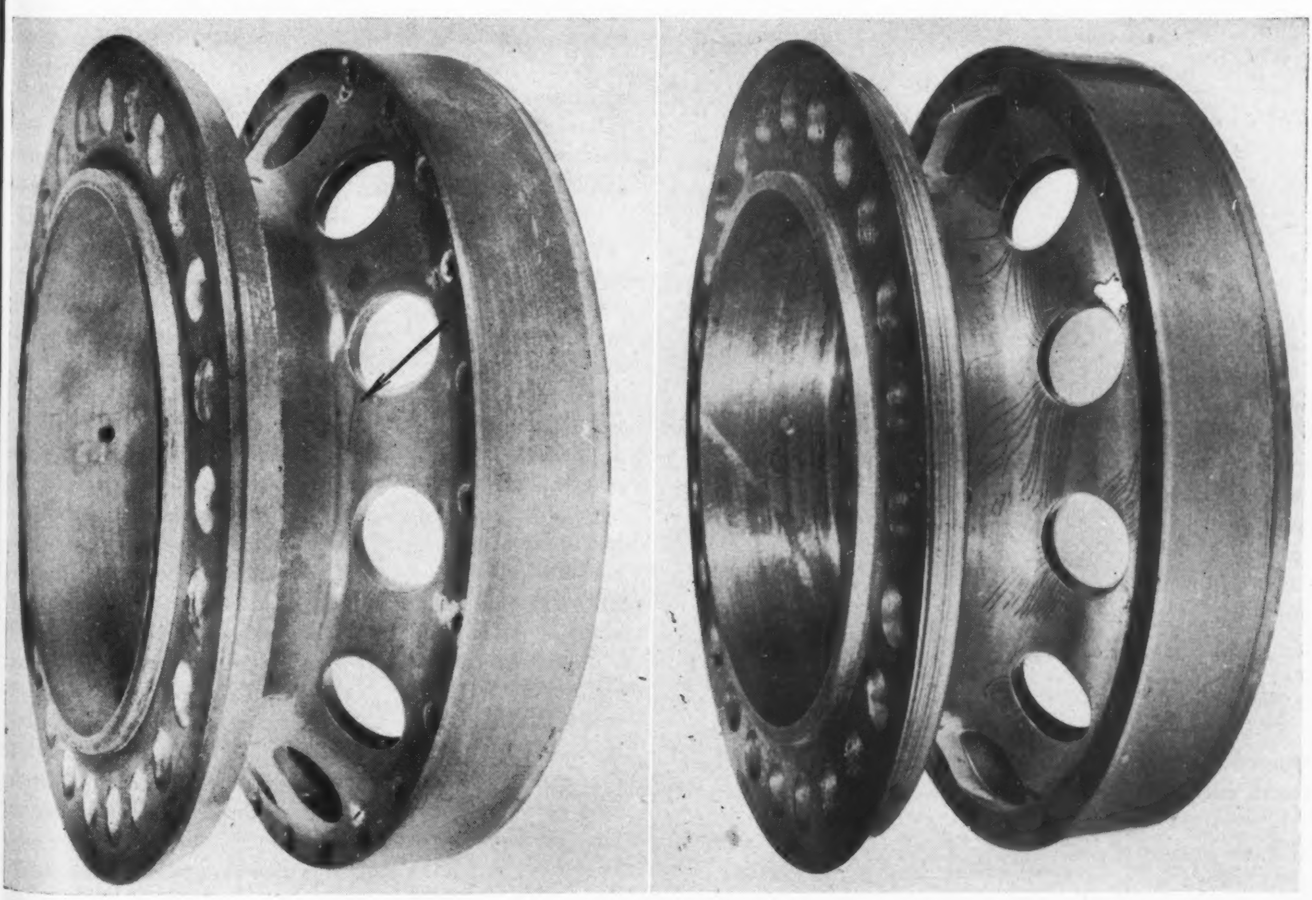
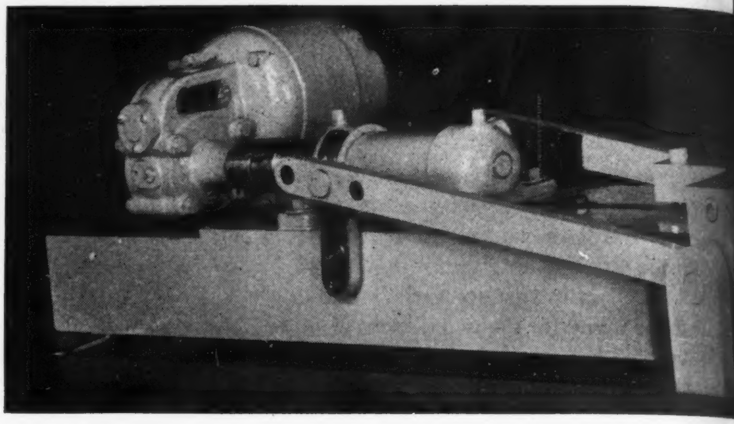
Fig. 8—*Generator bracket tested in cantilever bending shows point of highest stress indicated by crack in picture at lower left. Fully developed crack pattern is shown in right-hand view*



By H. W. Gillett
War Metallurgy Committee



Part III—Effects of Corrosion, Wear and Temperature

Choosing the Right Material

SOME tests have *no meaning at all* unless they are specifically planned to correlate with service. Such special tests include tests for corrosion resistance, for wear resistance, for properties as bearing metals and for resistance in high temperature service [Bearings and other special tests will be discussed in the following installment].

Corrosion Testing

Most types of corrosion of steel are not particularly affected by small changes in composition. Iron rusts, and whether it is of 99.9 per cent purity or a constructional steel containing 95 per cent iron, the iron is in the ascendancy and they all rust about alike. For ordinary steel, then, protecting by some coating—as by painting, enameling, or galvanizing—is necessary unless the corroding influence can be kept away by other means.

The nature of the corroding medium is of great importance, so in testing for corrosion resistance it is necessary to make sure that the actual corroding medium that will occur in service is used. Even with the correct corroding medium there is a tendency to use, when resistance to an acid is concerned, for example, a stronger solution of the acid so as to speed up results. This is seldom safe because the chemical reaction may be different. As a rough guide it may be said that in testing corrosion resistance in the laboratory, unless the corroded surface looks just like one corroded in service, the test will probably mislead rather than guide.

Changes in composition of the corrodent, changes in temperature, mechanical abrasion, presence of another metal, presence of lodged particles even though they are themselves inert, all affect the rate and type of corrosion and the retention or removal of corrosion products. The corrosion product governs the contact between the corrodent and the material being corroded; an impervious, varnish-like product tends to halt corrosion, a pervious one, or one that flakes off, does not.

The height of absurdity is reached when resistance to an acid is taken as an indication of resistance to atmospheric corrosion, or when the salt spray test is considered to give data directly applicable to any other than salt spray conditions. Tests like the salt spray can be helpful in revealing nonuniformity of a coating, for example, but they are far too often relied upon to evaluate "corrosion resistance" when they have no relation at all to service[1].

Galvanic attack cannot be safely predicted from the "electrochemical series": First, because the order of corrodibility of the metals in the series may shift as the composition or concentration of the solution is varied; second, because the products of corrosion often act as electrical insulators and slow down or stop attack that would be expected to occur. On the basis of the electrochemical series the engineer might avoid combinations that a test, duplicating the conditions of service, would show to be practical and useful.

In atmospheric corrosion the real question may be not so much what the bare metal will do when it is bare, as how well it will hold paint so as not to become bare, and here the mutual behavior of all kinds of metals and all kinds of paints comes in for consideration.

Actual exposure to the atmosphere, to soils and to sea water over long periods, 5 to 20 or more years and in many localities, is involved in some of the corrosion programs carried out by the American Society for Testing Materials, the U. S. Bureau of Standards and the British Iron & Steel Institute. The materials so evaluated by long exposure to natural conditions have, in some cases, been used as guinea pigs by which proposed "accelerated"

[1] Sample, C. H.—"Use and Misuse of the Salt Spray Test as Applied to Electrodeposited Metallic Finishes", A.S.T.M. *Bulletin*, Aug., 1943, Pages 19-24.

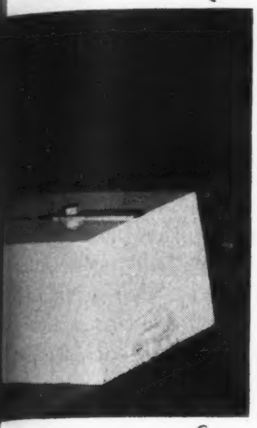


Fig. 17—Wear testing machine which closely reproduces actual service conditions. Used in study of machine beds and carriages, tester reciprocates two short pieces over two long ones

test methods might themselves be evaluated.

The American Petroleum Institute has published a code "for determination of resistance to corrosion of metal samples in petroleum refining processes" which relates chiefly to putting the specimens into the actual commercial environment and taking them out at intervals for inspection and measurement, rather than to laboratory testing. A more general technique of this type is described by the A.S.T.M.[2].

The chemical industry has evolved certain laboratory tests, especially for stainless steels, the conditions of which are rigidly set forth to insure reproducibility of results, but discussion may yet be had on the interpretation of results because they do not necessarily represent the conditions under which the chemical engineer plans to use the materials, even though he buys them on the basis of the test results.

The details of salt spray testing are set forth in Navy and in A.S.T.M. specifications, again to insure reproducibility of results. Interpretation is another matter.

A good bird's-eye view of some of the surviving corrosion test methods, flexible enough to permit their application to a range of materials and environments, is included in the section on corrosion *Nickel and Nickel Alloys* published by the International Nickel Co.

The "corrosion-cracking" propensities of brass, primarily due to unrelieved internal stresses, are tested for by immersion in mercurous nitrate solution, and the details have been standardized[3]. This is not a corrosion test in the ordinary sense; it is a means of making internal stresses reveal their presence.

In the copper alloy industry special tests have been worked out to evaluate the selective corrosion, "dezincification" of brass and the properties of condenser tube alloys by means of an "impingement" test, and other special properties by other tests.

Even so apparently simple a test as that for corrosion in a liquid is not a matter of sticking a piece of metal in a solution and letting nature take its course. The relative volume of solution to exposed area of metal, whether the specimen is to be stationary or moved in the liquid at a definite speed, whether the liquid should be circulated, whether the solution should be continuously filtered and recirculated, whether the corrosion products should be allowed to accumulate, whether fresh solution should replace the old, whether the corrosion products should be removed constantly as by rotating the specimen against a brush or given an opportunity to adhere by periodic drying, and so on, all comes in.

The way the results are reported also has to be decided; for example, as weight gain per unit area after drying with corrosion products in place, as weight change after brushing off loosely adhering corrosion products, as weight loss after removing corrosion products by some chemical method that removes them without attacking the metal, as number and depth of pits (the latter expressed in inches penetration per year), as the change in mechanical properties of, say, a tensile specimen subjected to corrosion and then tested, or as change in electrical resistance. When the problem is not so much the rate of attack on the metal as the rate of contamination of the solution, results will be given in terms of chemical analysis to show pick-up, or of weight of sludge formed.

Initial Corrosion Is Critical

There is, in atmospheric corrosion, always the question whether the initial coat of corrosion products is produced under one or another set of atmospheric conditions. Speller[4] reports that some steel and wrought iron pipe, left by the French on the Isthmus of Panama and exposed

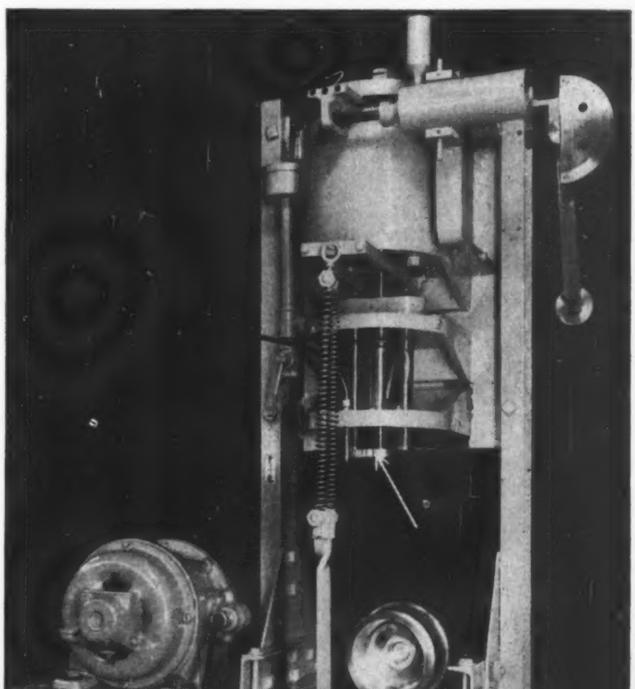


Fig. 18—Device for testing wear in which specimens are slid together without any rolling action. To further simulate service, materials may be enclosed in any atmosphere, heated or run with an abrasive

[2] A.S.T.M. Tentative Recommended Practice for Conducting Plant Corrosion Tests, A244-39T.

[3] A.S.T.M. Tentative Specification B111-39T.

[4] Speller, F. N.—*Corrosion, Causes, and Prevention*, McGraw-Hill Book Co., 1935.

to the atmosphere for 20 years, were found "almost as good as new, but others were almost destroyed by rust". It was concluded that the pieces that were resistant were first exposed during the dry season and their initial rust coating was dried out into a protective film, while the badly corroded ones did not have an opportunity to produce any but a loose, nonprotective rust coating.

Gregg and Pray[5] sought to refine the laboratory procedure of controlling the composition of atmospheres used, the cycles of humidity and drying out, so that behavior of steel under atmospheric corrosion during a period of years could be estimated by testing for a few months or even weeks. On the basis of comparison through weight changes and change in properties of tensile specimens with behavior on actual exposure in several localities for several years, they were successful in securing acceleration with reliability, *provided* the initial rusting of the specimen was started by actual atmospheric exposure before transferring the specimen to the test equipment. None of the various efforts to control the initial rusting in the laboratory quite duplicated the way nature controls it.

The salt spray test, pertinent for metals destined for marine use under actual spray conditions, and pertinent as a method for showing up porosity of some, but not all, metallic and other coatings on steel, has often given misinformation when the results are taken as having broader than their true meaning. That the salt spray test decisively reports cadmium plate as superior to zinc plate—but for atmospheric corrosion protection on steel in actual service the two are often equally useful, or zinc may be appreciably better—is often cited as an evidence of the way this test can mislead.

Development, by some carefully chosen laboratory method, of the same type of corrosion that occurs in service can be used to secure data that have meaning. For example, intercrystalline attack upon some heat-treated but too-slowly cooled aluminum alloys weakens them by formation of surface fissures, but without appreciable weight change of the part as a whole. Such attack develops on long exposure to certain corrosive atmospheres. Similar attack was rapidly produced at the U. S. Bureau of Standards by intermittent immersion of tensile or fatigue specimens for suitable cycles in a suitable solution and then determining the mechanical properties. That sound conclusions could be drawn from the laboratory tests, for which the microscope showed that the same type of attack had been produced as occurred in service, was later demonstrated by prolonged exposure tests of other specimens.

When stainless is to be welded or to be subjected to elevated temperature within a certain range, the stability of the condition of the carbide is important since, if carbide is thrown out in that temperature range, weakness around the weld and decreased resistance in the affected zone to some types of corrodents may occur. Hence, in the "Strauss" acid copper sulphate and similar tests, corrosive conditions are imposed in the test that are not at all expected in service; the corrosion behavior is merely used as an indicator of a structural condition. Other means for detecting this structural condition have been worked out[6] which are quicker and simpler and can be applied nondestructively to fabricated structures.

[5] Gregg, J. L., and H. A. Pray—"An Accelerated Atmospheric Corrosion Test", *Proceedings*, A.S.T.M., 1941, Vol. 41, Pages 758-765.

[6] Russell, H. W., H. A. Pray and P. D. Miller—"Detection of the Susceptibility of 18-8 Steel Castings to Intergranular Corrosion" *Transactions* American Foundrymen's Assn., Vol. 50, 1942, Pages 918-930.

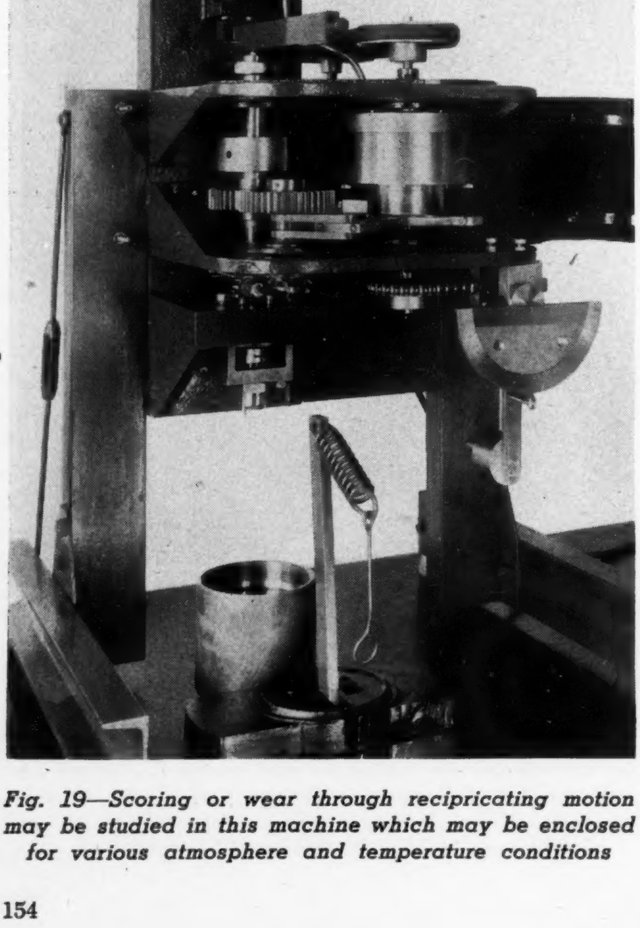


Fig. 19—Scoring or wear through reciprocating motion may be studied in this machine which may be enclosed for various atmosphere and temperature conditions

Fatigue Stresses Accelerate Corrosion

It is now well known that repeated stress combined with simultaneous corrosion is far more damaging than the mere roughening or pitting due to corrosion prior to application of repeated stress. Just as in plain corrosion, corrosion fatigue is influenced by chemical composition. This is, however, more in evidence among nonferrous alloys and among the highly alloyed "stainless" steels but little in evidence among everyday as-rolled, normalized or quenched and tempered steels. Avoidance of corrosion-fatigue failures of constructional steels is therefore generally to be accomplished by preventing corrosive liquids from coming into contact with the steels under repeated stress, not by adjusting the chemical composition.

Sucker rods used in pumping oil wells under corrosive conditions are sometimes highly alloyed in order to secure resistance to corrosion fatigue. Unfortunately the corrosive conditions vary so greatly that the order of excellence of two steels used in two different wells may be reversed. It is said that under sulphide corrosion conditions none of the many alternative steels that would serve in absence of corrosion are equivalent to the nickel steels of the 4600 series. However, enough has been done on nickel plating to indicate that instead of putting considerable nickel in the steel, a little outside the steel may serve as well. There are plenty of cases where it makes more sense to engineer a product out of a difficult set of circumstances than to throw in more alloy.

An important type of attack which may occur in heat treatment can be classed under corrosion. This is when heat-treatable steels, or those for normalizing, are heated in air or in products of combustion; they oxidize and scale, also some of the carbon near the surface may be burnt out so that the steel has a decarburized "bark" or soft skin, lower in carbon than the interior. When attempts are made to reduce scaling by bathing the steel with unpurified products of combustion, decarburization is likely to be accentuated. Soft skin is obviously bad from the points of view of wear resistance and of fatigue resistance. To avoid scaling and decarburization at the same time, "controlled atmospheres" for heating have come into wide use.

Low Alloys Facilitate Atmosphere Control

In the higher alloy S.A.E. constructional steels, some slight difference in propensity toward scaling or decarburization can be found, but this is small compared to the differences at different carbon levels, irrespective of alloy content. When a N.E. steel is substituted for a S.A.E. steel, each ordinarily is at the same carbon level and the controlled atmosphere previously used will probably be equally effective. Substitution of low alloy N.E. steels for S.A.E. steels of higher alloy content, on the whole, facilitates rather than hampers the selection and control of a suitable atmosphere.

Corrosion at elevated temperatures as by air, flue gases, sulphurous gases or those with unusual chemical constituents, has even greater difficulties in selection of a revealing test than at ordinary temperatures, though quite similar phenomena may occur. The type and adherence of the initial corrosion product is of great importance. Often there is opportunity for its removal by jarring, flexing, abrasion or mere expansion and contraction in heating up and cooling off. Intergranular attack at elevated temperature is prevalent among metals that form poorly adherent films, and its possibility needs always to be considered in planning a test. This, as well as pitting and reduction of cross section through scaling can introduce serious complications in testing for other high-temperature properties.

Wear Testing

Wear is an undesired change of dimensions in service resulting from pressure and sliding exerted by some other body. The definition includes the battering type of wear, where material is pushed where it is not wanted but not necessarily removed from the part.

Even what would ordinarily be appraised as "metal-to-metal" wear is often caused by abrasive which has been rolled or scraped between the surfaces, grinding them away. Small amounts of abrasive often cause serious wear. Furthermore, the wear debris is itself an abrasive and has to be considered. Especially during the wearing-in period wear debris is produced as inspection of crankcase oil from an automobile engine during break-in will show clearly. Such debris is a type of grit and whether it is promptly washed out by oil or held between the surfaces makes a big difference. Reciprocating motion rubs trapped debris back and forth instead of letting it be easily washed out, so reciprocating service demands a reciprocating type of test.

True metal-to-metal wear is often closely akin to pressure welding, in that metals—softened by frictional heating, rubbed clean of all surface films—are pressed together into welding contact and do weld; but relative motion then pulls them apart, leaving chunks of torn-out metal adhering to the other part or soon loosened from it and appearing as wear debris. In this type of wear an antiwelding film, such as oil, oxide, or some chemical compound resulting from attack of the metal by the chemicals in "extreme pressure" lubricants, prevents metal-to-metal welding and wear as long as it remains intact.

A temporary coating is often utilized to avoid welding while the worn-in coating is being built up, such as a tin or cadmium flash on pistons. That a chemically produced coating of aluminum oxide, a strongly abrasive material, on the surface of an aluminum piston reduces wear on the cylinder walls indicates the powerful effect of adherent antiwelding coatings. The surrounding atmosphere is often a factor in the formation of antiwelding films, and humidity definitely has an important effect.

Resistance to abrasive wear generally increases with hardness because in abrasive wear the abrasive must get a toe hold beneath the surface to exert a prying, chisel-like action. If it cannot penetrate somewhat, it cannot tear off particles, though it can batter or peen, but this too is resisted by hardness. If the abrasive penetrates a bit and begins to pry, then toughness comes into play to keep chips from being pried out. With one of a pair of metals soft or porous so grit is trapped, the opposing harder surfaces wear the faster.

A combination of battering and abrasive wear, as in a jaw crusher, demands a material both hard and tough. This opposed combination of properties is obtained from Hadfields' manganese steel which, though soft and tough when put into service, becomes intensely hard on the surface under the battering service but retains its core toughness. Without the battering action which hardens this steel it fails miserably from abrasive wear.

Ability to wear-in and glaze under operating conditions is highly helpful against welding and seizure. Cast iron is often one of the best choices for wear resistance, due to the glazing ability given by its graphite flakes. One generalization about cast iron for metal-to-metal wear

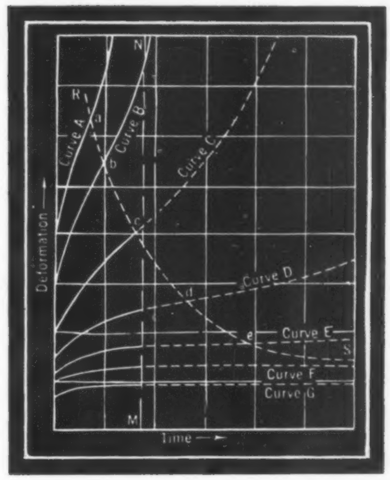


Fig. 20—Schematic plot of typical creep curves for different stresses ranging from high load curve A to low load curve G at constant temperature

is that cast iron with free iron crystals (free ferrite) is usually very poorly seizure resistant. It should be noted that neither the chemical analysis of a cast iron nor its ordinarily determined mechanical properties gives assurance of absence of free ferrite. It is avoided by proper additions at the end of the melting operation, but whether these have been properly made can only be shown by metallographic examination or wear testing.

Qualities of Wear-Resistant Materials

As to wear-resistant materials and assemblies, utility is shown by materials that are smooth enough so local pressures on promontories are not excessive; that have shallow pools for retention of lubricant; that are hard like nitrided, chromium-plated, case-carburized or flame or induction hardened steels; or that contain extremely hard constitutents in their own matrix as do high-carbon, high-chromium steels but, in spite of hardness, are not too devoid of toughness.

Some so-called wear testing devices sometimes press a rotating disk or cylinder of a hard metal or even of tungsten carbide or the like against a flat surface of the metal to be tested and let it tear a gouge whose depth is taken as a measure of wear resistance. The test resembles no actual mode of wear save perhaps a wheelburn from a spinning driver on a railroad rail. If the test is made under an extreme pressure lubricant, it may show something about the ability of that lubricant to form an adherent coating. Such a test may develop heat checking and give information of interest in that respect, but as a wear test, it is close to useless.

If service conditions are not too greatly exaggerated the brake-shoe type of test—where the surfaces represent the materials that are to work against each other in service, surface finish is duplicated, and careful measurement is made of pressure—can give useful information on the way the surface wears in, on the relative wear of each of the coating surfaces and on how much pressure the combination will stand without seizure. If the outfit is rigged as a floating, pendulum dynamometer as in the Amsler machine, useful indications on seizure behavior may be had.

Actual service wear is seldom as free from complicating factors as is a simple brake-shoe test. The operating temperature needs to be considered, since the rate of heat removal in the test may be far different from that in service. Thus control of temperature is important.

In pure abrasive wear testing—as where sand is ground into a surface by disk pressing the abrasive into contact, using sandpaper, carrying out a sandblasting operation, or dragging a piece like a plowpoint through a channel filled with sand—the experimenter soon finds that he is testing the abrasive as much as the metal and has to take great pains before he can secure reproducible results. Whether the sand in the plowpoint test is wet or dry, may bring about a reversal of results.

Sleuthing out all the attendant factors in wear is not an easy task. Cylinder corrosion from moisture condensation as the engine cools is a factor that is not easily introduced in a wear test setup. The various types of wear-testing machines and special devices have been discussed at some length and the literature of wear and wear testing is extremely extensive. A few of the many types of special machines used for studying wear are illustrated in *Figs.* 17, 18 and 19.

There is a type of wear between mating parts that are not supposed to move, but do, termed "chafing" or "fretting" which is related to galling. In a press fit, a keyway or other close contact between metal parts, extremely minute motion may occur under repeated stress. This is readily noticeable in fatigue testing of hard steel specimens held in hard grips. Although the grips may be clamped tightly, there is often sufficient motion to cause galling and tearing off of particles so minute that they oxidize at once, i.e., they are pyrophoric, "burning" in air without the surrounding temperature having been raised to the ignition point of massive steel.

If lubrication could be supplied, the trouble would be largely avoided. Greasing the surface will give temporary protection. Introduction of a gasket or weld-preventing film such as leather or paper, or of a soft metal film such as electroplated copper may be necessary between the mating faces of a press fit. However, welding or brazing the parts together to make the joint solid may be required. The benefit of plating in ameliorating galling has been mentioned by Barish[7] in connection with aircraft propeller mountings.

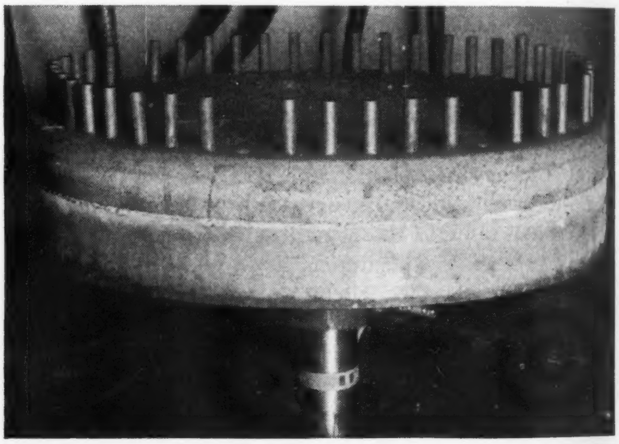


Fig. 21—Specimen holder for scaling tester in Fig. 22

The roughening of the surface by chafing within a press fit produces stress concentration and often leads to fatigue failure. Since the surfaces are not where they can be inspected, such wear is insidious. Chafing occurs under repeated stress and the stress concentration it produces is detrimental under repeated stress. The phenomenon is one of wear, but its occurence is related to fatigue. Obviously, the motion involved is so small that it is difficult to reproduce exactly in a testing outfit, so close attention needs to be given to exact simulation of service.

High Temperature Testing

Uses for metals at high temperatures in furnace parts; in oil stills and other equipment for the petroleum industry; in high pressure, high temperature steam power generation and conversion to electrical energy; in pressure

[7] Barish, T.—"Antifriction Bearing Developments for Aviation Engines", *Transactions* A.S.M.E., May, 1943, Pages 261-266, sup. 266.

vessels for the chemical industry; in engine parts, etc., seldom present simple problems. The service conditions usually demand resistance to more than one deteriorating factor. The parts are often bathed in hot gases of combustion which, despite the combustion engineer's terminology of "oxidizing, neutral and reducing flames" as relating to completeness of combustion and content of carbon monoxide, are generally strongly oxidizing. Chemically reducing conditions are sometimes met and the atmosphere may change from reducing to oxidizing, in normal service.

The fatigue problem is ordinarily overshadowed by other problems, at least at the higher part of the high temperature range. In those cases in which a long service life is inherent in the design, the loads which produce the low limiting creep rates and total deformations are considerably lower than the endurance limit, so creep rather

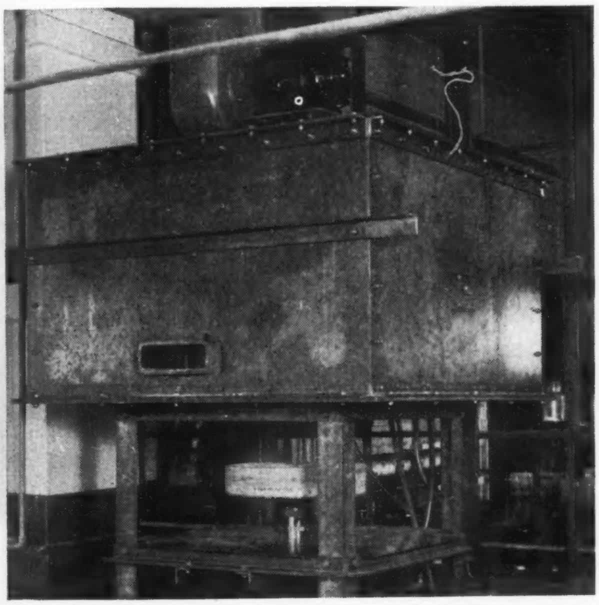


Fig. 22—Scaling tester for valve steels. Specimens rotate into a flame and then into a water-cooled tunnel, at 1800 and 650 degrees Fahr. respectively, each cycle taking 40 minutes during a 200 hour test. In spite of efforts to simulate conditions, results do not correspond exactly with those of service

than fatigue is the controlling design factor. In cases where a limited service life is the basis for design, resulting in high loads and appreciable allowable deformations, the stresses which produce fracture in 1000 hours are sometimes of the same order of magnitude as the endurance limits. Fatigue problems, therefore, need to be considered.

Damping capacity of alloys used at high temperatures is known to vary considerably with composition. Care must be taken so that, in materials with low damping capacity, vibrations do not build up stresses in excess of the fatigue limits. It is a disturbing factor that in many high-temperature fatigue tests, there is no apparent tendency for the stress-cycle-to-fracture graphs to level off and develop an apparent endurance limit as in the case of many steels at room or moderately elevated temperatures. Fractures have been obtained in some austenitic alloys after 2.5×10^8 cycles at 1200 degrees Fahr. Until tests of still greater duration are available, it is conservative to assume that at still lower stresses fractures may occur after a considerably greater number of stress reversals. However, a considerable program of high temperature fatigue tests, in specially designed apparatus[8], is under way which should make clear how far the designer can continue to disregard the fatigue question in relation to high temperature behavior.

Allowable Deformation Governs Selection

The requirements in some cases, as in steam turbines, necessitates freedom from deformation, while relatively large deformation is acceptable in some furnace parts with "air-fits". The criterion as to permissible deformation in determination of load-carrying ability, or what might be termed "long-time high-temperature yield strength" or "creep resistance", therefore, varies widely.

It would be convenient to be able to say that a material has a certain creep strength at high temperatures of so many pounds per square inch analogous to the yield strength used in engineering design at normal temperatures. The trend is toward running creep tests at a series of loads on the material in question at the desired temperatures and from the creep curves to evaluate the stresses required to produce certain rates of deformation such as 1 per cent in 10,000 or 100,000 hours. Obviously such an evaluation involves appreciable extrapolation and the trend now is toward quoting the actual rates in per cent per hour for the various stresses used, or giving the stresses to produce a rate of deformation of .01, .1, and 1 per cent deformation in 1000 hours. With these data and the actual time-deformation curves, the design engineer is fully acquainted with stress-time-deformation characteristics of the material under test. The difficulties of obtaining reliable creep test data are enormous compared to determining room temperature yield strength.

In the lower range of temperature, where ability to work harden or strain harden still exists, the part may get better as it stretches. If some initial deformation is permissible, deformation thereafter slows down or even stops entirely. At higher, annealing, temperatures this is not the case and, at a sufficiently high load, stretching will occur and continue until the part stretches and necks down to too small a cross section to carry the load in the extreme case. If in forcing a material to the extreme temperature it will stand, it is used just on the boundary between strain-hardening on one hand and annealing on the other, obviously small changes in operating temperature or in testing temperature will vastly affect the results. This boundary is not clear cut; strain-hardening tendencies and annealing tendencies compete over a broad range of temperature. Hence the precision of temperature control required in accurate creep testing has to be much greater than is commonly required in anything else confronting the testing engineer.

It is true that, in service, analogous uniformity of operating temperature is seldom or never achieved, but to evaluate potentialities of materials and to indicate what stresses and temperatures can be endured and still obtain

(*Continued on Page* 252)

[8] Welsh, W. P. and W. A. Wilson—"A New High-Temperature Fatigue Machine", *Proceedings*, A.S.T.M., Vol. 41, 1941, Pages 733-745.

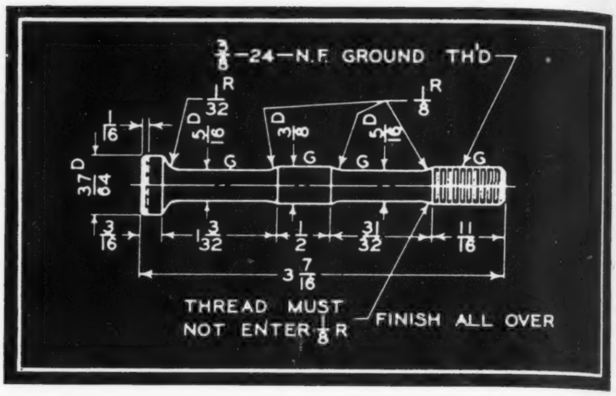


Fig. 1—Detail of bolts used in fatigue tests discussed in this article. Note necked-down shank and generous fillet radii

Tightening Is Vital Factor in Bolt Endurance

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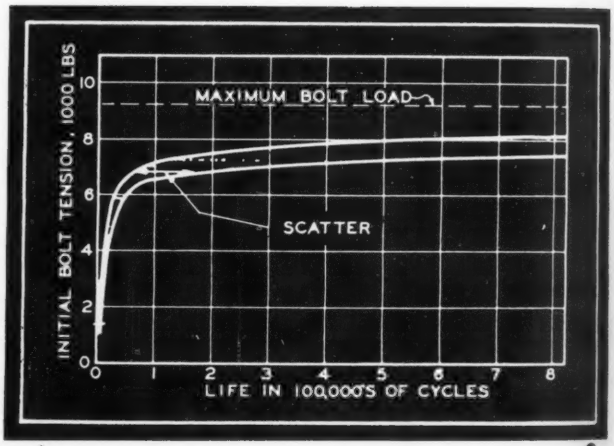

Fig. 2—Curves indicate the profound effect which initial nut tightness has on bolt life

STRENGTH of most highly loaded bolts and studs is determined by the man with the wrench and not by the designer, the metallurgist, or by the manufacturing processes. In highly loaded bolts and studs, it is only rarely that design is so bad, fabrication practice so poor, or the material so weak as to cause failure in service providing that the nut is properly tightened against reasonably rigid members.

There are, of course, advantages to be gained by careful design. Good materials and heat treatments should be used and some manufacturing practices are better than others. But all of these are relatively unimportant in severe service compared to proper tightening of the nut during assembly*.

A properly tightened nut is one that applies a tensile load to the bolt or stud equal to or greater than the external load to be supported in service. When this condition is fulfilled and maintained, the bolt cannot fail by fatigue because it can experience practically no change in stress regardless of the fluctuating nature of the operating load. It cannot fail statically because, to be tightened as specified, it must be capable of supporting the greatest operating load.

Numerous fatigue tests have shown that the fatigue strength of metal decreases as the range of dynamic stress (stress change) to which the metal is subjected is increased and, conversely, that the fatigue strength is increased as the dynamic stress range is decreased. As the stress change approaches zero, the dynamic load that can be supported approaches the tensile strength of the material.

Consider the case of a bolt subjected to fluctuating load, such as in a connecting rod. If the nut is tightened just enough to make contact with the bearing cap, the load that will be applied to the bolt will vary from zero, the initial tightness, to the maximum inertia load of the piston and connecting rod. Under this large stress change, the bolt strength will be less than one-fifth its value under static load and fatigue failure can be avoided only by making the bolt very large. If the nut is now tightened so as to load the bolt to one-half the inertia tensile load, the stress change will be one half as great and the bolt's operating strength may be one-third to one-half of its static strength. When the nut is tightened against reasonably rigid abutments to produce tension in the bolt equal to or greater than the working tensile load, there is practically no stress change in the bolt and its operating strength will therefore approach its static strength.

Increase in fatigue strength of bolts with increase in initial tightness is shown by a series of fatigue tests on bolts that were

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Abstract of a paper presented at the recent War Engineering Annual Meeting of the Society of Automotive Engineers in Detroit.

*Methods of tightening are discussed by Mr. Almen in "Bolt Failure as Affected by Tightening", MACHINE DESIGN, Aug., 1943, Page 134.

dimensioned and processed as shown in *Fig.* 1, in which the external load applied to the bolted members alternated from zero to 9215 pounds. One group of 17 bolts was fatigue tested with the nuts tightened to produce initial bolt tension of 1420 pounds. The load in these bolts, therefore, alternated from a minimum load of 1420 pounds to a maximum of something more than 9215 pounds, a load change of nearly 8000 pounds at each load application. The average fatigue durability of these bolts was 5960 cycles.

Another group of 16 bolts was fatigue tested with the nuts tightened to an initial bolt tension of 5920 pounds. The load in this group, therefore, ranged from 5920 pounds to 9215 pounds, or a load change of approximately 3300 pounds at each load application. The average fatigue life of this group of bolts was 35,900 stress cycles.

Endurance Increases as Stress Range Decreases

In a third group of 15 bolts the load alternated between the initial nut tension of 7220 pounds and 9215 pounds, a load change at each load application of about 2000 pounds. The average fatigue life of this group was 214,500 stress cycles.

In the fourth group only two bolts were tested, one failing after 4,654,000 stress cycles. The other had not failed when the test was stopped after more than 10,000,000 stress cycles. These bolts were initially tightened to 8420 pounds and since the external load was the same as for the other groups, the load change at each load application was only 800 pounds.

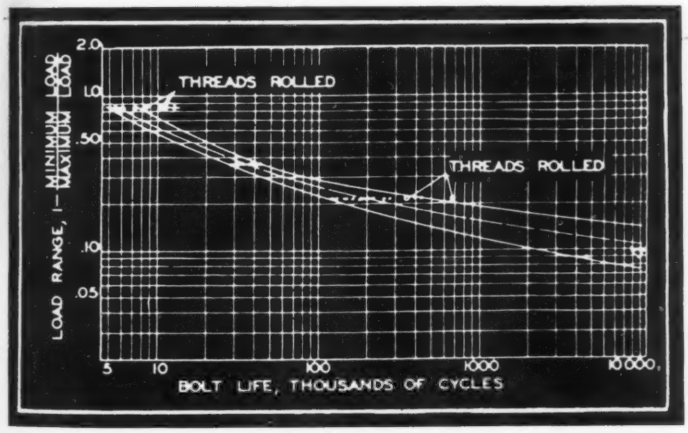
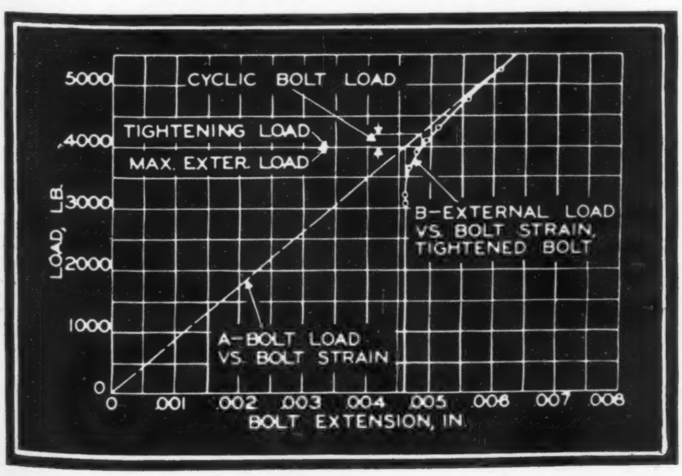


Fig. 3—Above—Log-log plot showing the influence of load-variation magnitude on bolt durability

Fig. 4—Below—Typical plot of stress-strain data illustrating the determination of cyclic bolt load



Results of these tests are graphicaly shown in the chart of *Fig.* 2, in which the initial bolt tension in pounds is plotted against fatigue durability in stress cycles. Test points for the two bolts tightened to 8420 pounds initial tension are not shown because their inclusion would require contraction of the life scale to undesirable proportions.

These test data are also shown in the log-log plot in *Fig.* 3, in which the load or stress range to which the bolts were subjected is plotted against durability in stress cycles. For this plot the stress range R is calculated as: $R = 1$—Minimum stress/Maximum stress. Log-log plotting is used because the lines joining the test points are only slightly curved which permits estimating the trend of the curve between test points and also permits projecting the curve into the fatigue endurance limit region.

Note that there is a considerable variation in bolt durability in each group of bolts tested. Similar fatigue life variability occurs in all kinds of specimens because it is impossible that any specimen can be exactly like any other specimen, just as no person can be exactly like any other person. Fatigue life variability among these bolts, as shown in *Fig.* 3, is small as compared to the life variability of other types of machine parts. The life ratios of the best to the poorest in each group, in decreasing order of stress range, are 1.5, 1.65 and 4. Although there are not a sufficient number of tests in each group to definitely establish the scatter band limits, increased scatter with increased life can be expected from the nature of the fatigue curve. Bolt fatigue test data that have been covered in the above are summarized in the table "Bolt Fatigue Test Data".

Stress Fluctuation Unavoidable

When the nut is insufficiently tightened, each load application will elastically elongate the bolt and a gap will be formed between the bolted members; the magnitude of this will be reduced as the initial tightness is increased. When the nut is tightened to near the operating load, this separation of the bolted members will not occur, but there will, nevertheless, be a small elastic elongation of the bolt.

When the nut is tightened, the bolt is elastically elongated and, at the same time, the bolted abutments are elastically shortened. The amount of such shortening depends on such variables as the design, the elastic characteristics of the bolted materials, and the area of the material supporting the bolt load. On application of the external operating load, the bolt is acted upon by the external load plus the load of elastic recovery of the bolted assembly. The sum of these forces will always be greater than the initial bolt tension and, therefore, the bolt will experience a change of stress at each load application regardless of the initial tension

magnitude. Stress change will be greater as elastic deformation of the bolted assembly is increased and reduced as rigidity of the bolted assembly is increased.

Bolt Fatigue Test Data

Initial Tension	Operating Load	Load Change	Stress Range	Average Life	Life Variation
1420	0 to 9215	8000	.85	5,960	1.5
5920	0 to 9215	3300	.36	35,900	1.65
7220	0 to 9215	2000	.215	214,500	4.
8420	0 to 9215	800	.087	5,000,000	...

Preliminary to fatigue testing the bolts described in the foregoing, stress-strain measurements were made for each bolt. The fatigue machine used for these tests is equipped with gravity scales whereby the load applied to the specimen may be accurately weighed at any position of the load-applying device. It was therefore a simple matter to take stress-strain measurements on each bolt while in place in the fatigue machine by weighing the load and measuring the bolt elongation at frequent intervals.

A typical plot of stress-strain data taken from one of the test bolts is shown in *Fig.* 4. In this plot the inclined straight line, having its origin at zero load and zero elongation, is the load extension curve of the bolt alone (Curve A). The plotted points, Curve B, were taken from a bolt that had been tightened against relatively

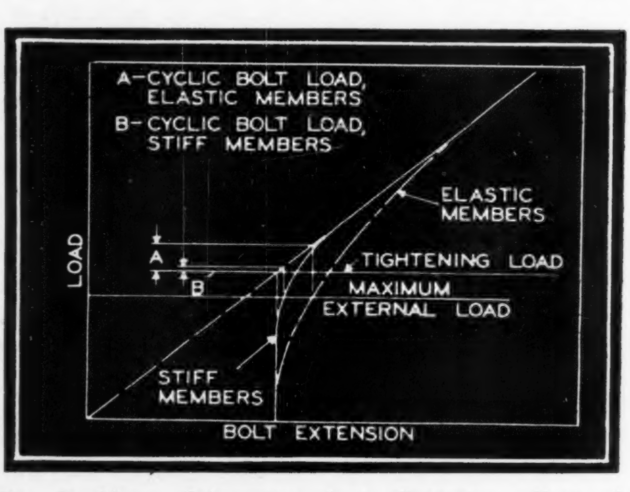
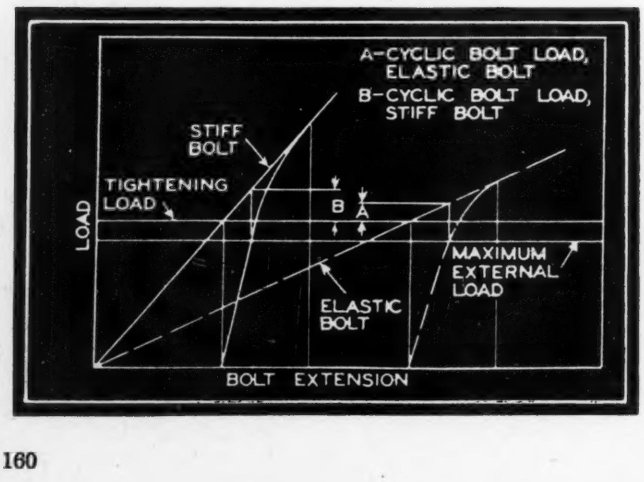


Fig. 5—Above—Schematic chart illustrates effect of elasticity on bolted members

Fig. 6—Below—Increase of bolt elasticity results in decrease of the cyclic bolt load



rigid abutments to an initial load of 4000 pounds, under which load the bolt elongated .0046-inch. With the external load applied to this tightened bolt, the load extension Curve B, as shown by the plotted points, does not rise vertically to join the inclined load extension curve of the bolt alone (A), as would occur under ideal conditions with an elastic bolt and perfectly rigid abutments. The plotted points (B) join the vertical line at .0046-inch elongation and the inclined line (A) by an easy curve, thus showing that the bolted members are elastic and that the bolt load is augmented by the elastic recovery of the bolted members.

Effect of Elasticity

This added load increment due to the bolted members' elasticity can be measured from the curves. For the case in which external load is equal to initial bolt tension, extend the bolt preload line (4000 pounds) to intersect the curve of the plotted points (B). The bolt extension thus determined is .00485-inch. Since extension under the bolt preload was .0046-inch, the bolt elongation has increased .00025-inch. Now project the new bolt extension line (.00485) vertically to intersect the load extension curve (A) of the bolt alone. This will correspond to a load of 4220 pounds or a load increase of 220 pounds over the initial bolt tension.

Load range experienced by the bolt under these conditions would be $1—4000/4220=.052$, a stress range so small as to be practically zero (see *Fig.* 3) and the bolt load is, therefore, almost static. In like manner, the resultant bolt load may be found for any external load whether it be greater or less than the initial tension on the bolt.

For the plot in *Fig.* 4, a fatigue test fixture was used in which the bolted members were relatively massive and rigid. Also, care was used to assure parallelism and smoothness of the contacting surfaces. For these reasons the elastic compression curve of the bolted members is so steep as to be immeasurable. It therefore coincides with the vertical preload line at .0046-inch bolt extension up to a load of about 3400 pounds. From this point the elastic curve (B) swings to the right and joins the bolt elastic curve (A) at about .006-inch bolt extension and 5220 pounds load. The elastic compression curve for this bolted assembly is such that external loads up to 3400 pounds add very little to the bolt preload. The nonlinear portion of the curve is presumably due to bending of the bolted members resulting from imperfect surfaces and to bending of the loading beam under the external load. As the external load is increased through the nonlinear range, the cyclic increment of bolt load above the initial bolt tension increases rapidly until complete separation of the bolted parts occurs at 5220 pounds and .006-inch bolt extension.

Schematically charted in *Fig.* 5 are two elastic curves which illustrate the effect of varying the elasticity of bolted members. From the method of analysis described, it will be seen that the cyclic load on the bolt is increased as the elasticity of the bolted members is increased. Similarly, *Fig.* 6 shows that the cyclic bolt load decreases as the bolt elasticity is increased. It may be said, therefore, that bolt strength is influenced by the design of the

bolted assembly and, in addition, by the materials used in the assembly.

A properly tightened bolt is weaker when used in combination with aluminum abutments than when used in combination with steel abutments of similar proportions because of the greater elastic deformation of aluminum. It will be weaker when used against abutments of small area than when used against abutments of large area. The number of parts making up the bolted assembly will also affect bolt strength because mating parts will always fit imperfectly, thus adding bending deflection to elastic compression. Therefore, each part will contribute to the overall elastic deformation of the assembly.

Bolt strength can be greatly affected by the arrangement of parts in a bolted assembly. An exaggerated case of this kind is shown in *Fig.* 7, in which identical parts are used in two assemblies. In one of these the bolt would be weak and in the other, strong.

Springs Can Help or Hinder

In *Fig.* 7A, a bolt is shown tightened against two stiff plates that are spaced apart by a low rate spring. The external load is applied against the bolt by the two stiff plates. In this case the coil spring is a part of the bolted assembly and, since it is very elastic as compared to the elasticity of the bolt, we may, for purposes of discussion, consider its rate to be zero. When an external load equal to the initial bolt tension is applied to the plates, the total bolt load will be twice the initial tension, because the spring load will not be appreciably reduced by the additional extension of the bolt and its load will be added to the external load. The stress range experienced by this bolt will, therefore, be $1-\frac{1}{2}=.5$. For the stress magnitudes of the bolts shown in *Fig.* 3, it will be seen that at stress range .5, early failure may be expected.

In *Fig.* 7B, the external load is also applied to the plates, but the low rate spring now is a part of the bolt instead of the bolted assembly as in *Fig.* 7A. Here, then, is a very elastic bolt tightened against relatively rigid members. When an external load equal to the initial bolt tension is applied to the plates, the load between the plates will be reduced to zero but the bolt will experience no appreciable change in load. The stress range will be $1-1=0$; that is, the load will be static and fatigue failure cannot occur (see *Fig.* 3).

Practical Elastic Considerations

While the arrangements shown in *Fig.* 7 are rather fanciful, we have assemblies in actual practice that are somewhat similar. *Fig.* 8 shows a condition frequently met in practice in which a gasket is clamped between two mating plates. The gasket is compressed locally opposite the bolt, thus bending the plates until they serve as the spring shown in *Fig.* 7A. When the external load is applied, the bolt will feel the elastic load of the bent plates plus the external load, a condition that invites trouble.

Also in such assemblies, the bolt or stud is usually short and relatively inelastic, presenting all of the conditions necessary for large stress range and resulting fatigue

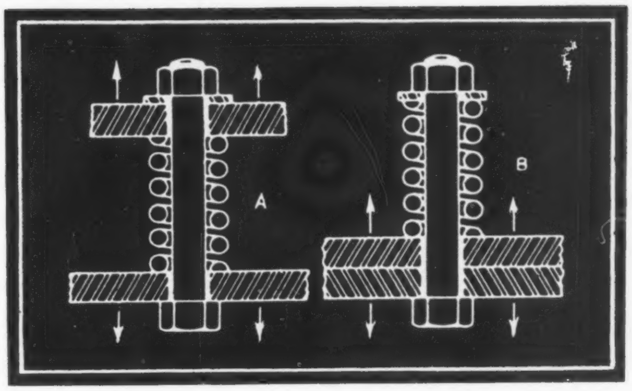
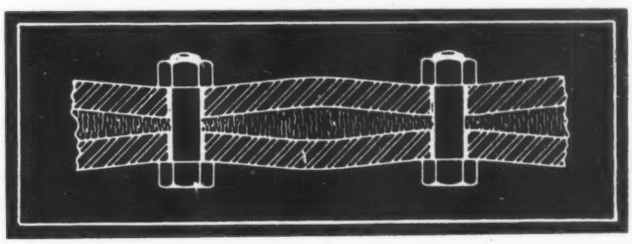


Fig. 7—Above—Effect of design on bolt strength. In A, spring is part of abutments—bolt is weak. In B, spring is part of bolt—bolt is strong

Fig. 8—Below—Elastically deformed plates and gasket increase maximum and cyclic bolt loads



failure. When gaskets are necessary, the gasket area should be large in the vicinity of the bolt and relatively smaller in proportion to the distance from the bolt. Thus the unit pressure on the gasket may be maintained with minimum bending of the bolted surfaces. The gasket should be as inelastic as possible, yet function properly as a seal.

A practical assembly having the characteristics of the assembly in *Fig.* 7B is shown in *Fig.* 9 in which a spring washer is clamped between the bolt head or nut and the bolted assembly. When such a spring washer is dimensioned to support, within its elastic range, the required external load or the initial bolt tension, whichever is the greater, the effective bolt elasticity is increased and, therefore, the bolt fatigue strength is also increased.

Likewise, any other expedient that will increase the rigidity of the bolted assembly or that will increase the elasticity of the bolt will increase the fatigue strength of the bolt.

Although properly tightened bolts are stronger as the rigidity of the bolted assembly is increased and as the elasticity of the bolt or stud is increased, a bolt or stud that is incapable of maintaining an initial tension equal to the external tensile load is quite likely to fail in severe service. Thus, relatively greater mortality exists among short bolts and studs than among long ones because of their lesser elastic yield.

Consider a short stud such as is often used to attach engine cylinders to a crankcase. Cylinder flange thickness plus washer thickness may be less than one-half inch. When the nut is tightened, the stud is elastically elongated throughout its length from near the bottom of the nut to near the last thread engaging the crankcase. Assuming that this distance is one-half inch and that the

nut, at proper tightness, stresses the stud to 120,000 pounds per square inch, the stud will then be elastically elongated .002-inch. If during operation, the bolted assembly is reduced in thickness by .001-inch because of wear, corrosion, embedding, or by displacement of material such as soft plating, the stud will lose one-half of the required tension and fatigue failure will follow.

Greater safety is assured when longer studs are used. For example, when, under the same conditions as described above, a stud of two-inch effective length is used, the loss of tension will be only one-eighth of the initial tension; that is, a loss of .001-inch from a total elastic elongation of .008-inch. This would be serious only when other factors, such as for example, initial tension, are near the low limit.

It will therefore be seen that among the major bolt and stud hazards, particularly when they are short, must be included loss of thickness of the bolted assembly as a result of surfaces that can embed, soft-plated coatings that can be displaced, gaskets that can be plastically compressed, materials that yield at elevated operating temperatures, etc.

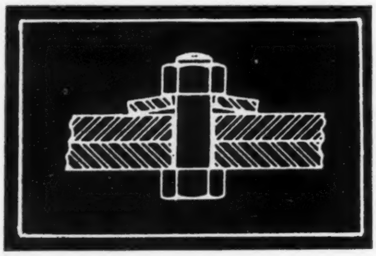


Fig. 9 — Illustrating how spring washer can augment bolt elasticity, resulting in longer bolt life

Yield Point May Be Exceeded

In tightening nuts it is far better to stress the bolt above the yield point of the material than to risk undertightness. Since for adequate size bolts the load is practically static, there can be no harm in yield providing the plastic deformation is not so great as to reduce the static strength of the bolt. The amount of yield that can be tolerated will depend on the length of the bolt, the design of the bolt and the characteristics of the material. When the bolt or stud body is equal in diameter to the outside diameter of the threads, yield will be concentrated at the roots of the threads whether the bolt be long or short. In such cases, little yield, as measured by bolt elongation, can be tolerated. For bolts or studs in which the body diameter is equal to or less than the thread root diameter, greater yield, as measured by bolt extension, can be tolerated, since yield will occur over the entire body length of the bolt.

It is not intended to recommend that all bolts should be tightened above the yield point but only to show that, where necessary, the practice may be followed provided proper caution is used. Necessity for tightening above the yield point would occur in such cases as when the bolt yield strength is only slightly greater than the maximum external tension load or when cotters are used in combination with castle nuts. In the latter case, it is often necessary to advance the nut beyond the required tightness in order to admit the cotter, since the nut should not be slackened to meet the cotter-pin hole. For short bolts, two cotter holes should be provided at such angles as to register with the nut notches at thirty-degree intervals, thus reducing overtightness which may be objectionable in critical cases.

Bending Loads

In addition to tensile loads, a large percentage of bolts and studs are subjected to bending loads of various magnitudes. Stress changes from repeated bending loads are generally of smaller magnitude than stress changes from tensile loads, but since these occur simultaneously, the stress change in the bolt will usually be their sum. As in the case of repeated tensile loads, the repeated bending loads, in normal designs, will be reduced as the nut tightness is increased and for the same reason. Also, as in the case of tensile loads, there will always be a small change in bending load regardless of nut tightness because of changes in the elastic deformation of the bolted members. When these changes in elastic deformation are not symmetrical with respect to the bolt axis, bending will occur.

By proper design, the effective bending-stress range can be increased or decreased independently of nut tightness. For extreme cases, it is possible to design the bolted assembly so as to throw the bending stress change out of phase with the tensile stress change. This can be done by elastically bending the bolt in a direction opposite to the bending induced by the external load, as for example, by drilling the holes in the abutments out of alignment by such amount that the bolt is straight when the tensile load is greatest. The effective stress change would then be that of the tension component or the bending component, whichever is greater.

Details of design and the finish of bolt shanks is perhaps of the same order of importance as the design and finish of the threads. The diameter of the shank should be made as small as possible consistent with required strength in order to increase bolt elasticity both in elongation and bending. Generous fillets should be provided at all section changes and the reduced diameter should be carried up to the threaded section. Additional gain may be obtained by compressively prestressing the shank surface as by rolling or shot peening.

Utilizing Spring Members

It is probable that in many instances spring members such as are shown in *Fig.* 9 can be profitably used. This would add to bolt elasticity, thus providing (1) greater safety against loss of tension by embedding, corrosion, yielding, etc., and (2) greater safety by reducing the stress range experienced by the bolt. Deflection of the spring member could probably be used as a measure of bolt tension with reasonable accuracy since deflection could be relatively great and therefore easily measured. It would be necessary to design these spring members to support the desired bolt tension within the elastic range of the spring and to avoid clamping them solidly against the abutments. They could be made in the form of disk springs or as beams depending on the available space, only one size being required for each bolt size.

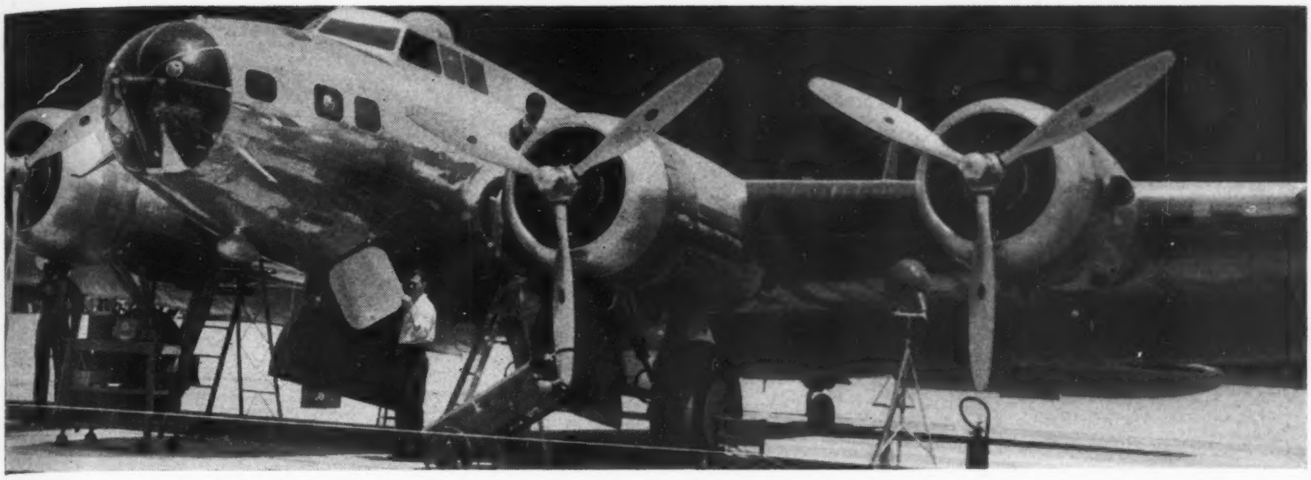


Fig. 1—Extreme conditions of serviceability are met by the trademark decalcomanias used on the propellers of aircraft

Decalcomanias Solve Nameplate Problem

By John W. Greve

WARTIME restrictions on metals for data plates, instruction plates, nameplates and the like have focused increasing attention on the possibilities of decalcomanias. To meet the more critical demands of present designs for durability, resistance to abuse, fast production schedules and other special requirements many improvements have been made which have resulted in new decalcomanias specifically suited to particular applications. Developments specifically for war use include nonspecular decalcomanias for camouflage applications and fluorescent decals for aircraft instrument dials and panels.

A decalcomania is essentially a film of many layers of colored varnish or lacquer and suitable adhesive, applied to a paper whose sole function is to carry the film until transferred to its permanent position. Designs are printed either face up or down, depending upon the nature of the transfer and the material to which it will be applied. The face-down type is printed in reverse order, visible colors being printed first followed by the backing colors.

Most transfers are of the face-up type because application by this method is quicker and less expensive. When open-letter designs are utilized, however, it is necessary to employ the face-down type to support the design until actually in place. For some applications, if clear film support of the open design is permissible, it is possible to use the more popular face-up type. Another form, for special locations, is double face, that is, it is readable from each side. Such decals may be used on a transparent panel in a door where the view from the exterior could be a colorful trademark or decorative treatment and that from the interior could show operating or service instructions, data, etc. This style has the attendant difficulties associated with the application of face-down decals and increases the cost probably 50 per cent. Usually it is better to apply two standard transfers in advantageous posi-

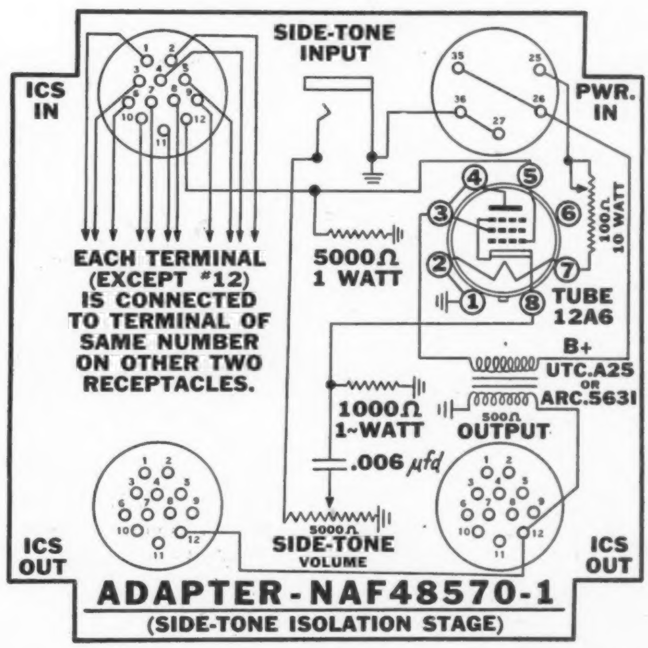


Fig. 2—Wiring diagram is legible for the life of electronic equipment to which it is applied

tions unless the advantages are sufficient to justify the special feature.

Color combinations and halftone illustrations are economically produced to effect attractive insignias or trademarks. These, when properly specified, may be applied to practically any type of surface including metal, wood, plastic, enamel, paint, varnish, shellac, crinkle finish, cloth or rubber. Some transparent colors are available for giving an illuminated effect when mounted on a transparent material. Usual recommendation for this style of decal is to limit the number of transparent colors employed, preferably to one.

One interesting application utilizes a decal with a transparent background behind the monogram section. The color of the machine shows through this section, thus providing a different combination of colors in the trademark for various machines although the same transfer is used on each. This could be applied to a series of machines even though all had the same finish by merely highspotting the section on which the decal is to be placed with a solid color according to the particular model.

Best suited to application on machines and equipment in the light fields, decals have nevertheless been developed to the point where they can be produced to be especially mar and abrasion resistant as typified by the propeller trademark shown in *Fig.* 1.

Intricate control panel markings and wiring diagrams can be reproduced easily and applied quickly and permanently. A typical example is the diagram illustrated in *Fig.* 2. Practically any design that is capable of being printed can be reproduced readily for affixing to a machine as a decal.

Other typical applications indicative of the extent to which decals may be used on machines are the nameplate and instruction plate on the gasoline engine in *Fig.* 3 and the nameplate on the domestic heating plant in *Fig.* 4. An instruction plate for servicing an aircraft landing gear is shown in *Fig.* 5. This particular decal has black lettering on a silver-color background.

Being a varnish or lacquer film, a decal does not have the durability of a metal plate but if properly applied, it should last throughout the life of the equipment. Precautions in application are desirable if best service is expected. They should not be placed on surfaces over which objects are moved in the normal operation of the machine. Neither should they be placed where the operator's hands would frequently come in contact with them. Although fingermarks and dirt can be removed easily the wear would result in deterioration.

Cost of decals is relatively small compared with etched or embossed metal plates. This is because decal paper is cheaper than metal whereas the other factors of applying a design to either a metal plate or a decal are on the average approximately the same.

A properly designed decal, carefully affixed in a location in keeping with the design of the machine, enhances its general appearance. If the decal tends to cheapen or detract from the appearance, the subject should be carefully reviewed to ascertain the fault. Usually it will be found that the decal is too gaudy or carelessly affixed.

In comparison with other materials, decals have practically no restrictions on their use. What WPB limitations there are apply to the supplier and may be summed up briefly: If functional — such as instruction plates—there are no restrictions, but if nonfunctional such as decoration or insignia 65 per cent of materials used in the same quarter of 1942 is the quota.

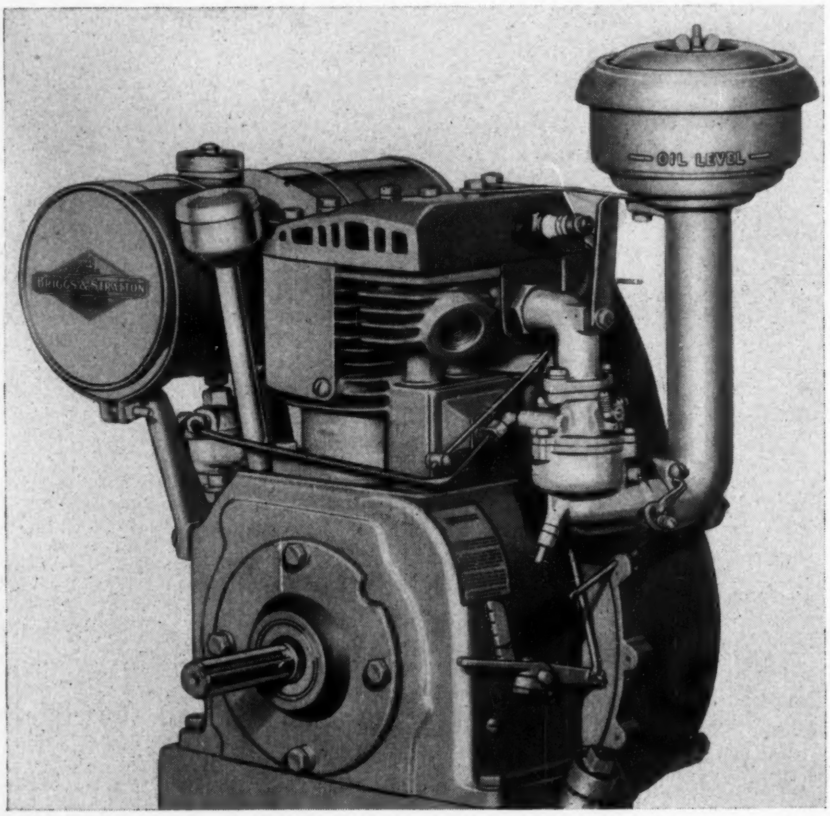


Fig. 3—Instruction data and nameplate on engine withstand normal abuse

This limitation has brought attention to another type of identification material known as self-adhesive labels. They have proved suitable substitutes for many applications and may be employed in extreme heat, cold, humidity and temperature changes. When protected with varnish, they are rendered impervious to salt water. Such labels are being used for patent and serial numbers, operating instructions, etc.

Paper stickers are often confused with decals. This is unfortunate because they do not have the same quality, either in appearance or life. Although many household appliances have used this type, the paper background affixed to the machine has a tendency to scuff and come loose at the edges due partially to the added thickness of the paper and to the deterioration of the paper itself.

Of the many types of decals available a few discussed briefly will serve to indicate the wide field of applica-

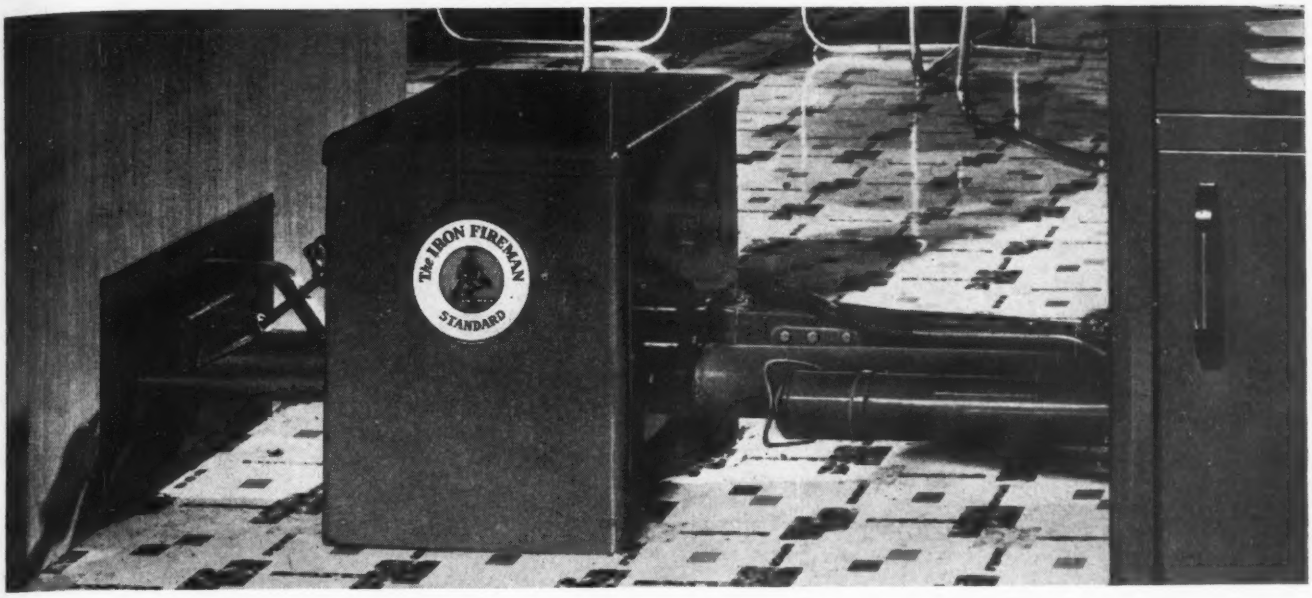


Fig. 4—Above—Domestic heating plant utilizes a decal trademark which has a high attention value

Fig. 5—Below—Aircraft landing gear struts employ this decal for service instructions

tions: For smooth painted, enameled, varnished, shellacked, lacquered or glass surfaces a water-applied, face-up decal with a color or clear lacquer background may be applied. This is the most common type and is suitable for high-speed production-line requirements. For metal, camouflage or rough surfaces a similarly applied decal is used but with a color background. For any surface except rubber or cloth a new exceptionally tough decal has been developed for solvent or cement application. Only available with color background this decal is a face-up type.

Another cement-applied decal but of the face-down type is available with open lettering or color background for application to any surface or raw wood. For heat resistant surfaces, special face-up or down decals may be applied with water or cement and have minimum color recession at high temperatures. For crinkle finish an open-type, face-down design is utilized with solvent application. For rubber, Vinylite, etc., an elastic film is applied with light pressure. Being of the face-down type either open lettering or color background may be used.

In solvent applications, the film is reduced to the consistency of wet paint when immersed in the application solution. This sets quickly when applied to the surface, effecting an excellent bond capable of withstanding extremes of heat, cold, wear or exposure.

Varnish-applied transfers are pure oil-paint colors and are used chiefly for lettering, trademarks and special designs. They are extremely durable but have the disadvantage of being applied face down. After the face side of the transfer is coated with a thin coat of cement and applied, the backing paper and tissue are removed. Then the decal must be thoroughly cleansed with water and benzine to remove the remaining tissue and gum. Failure to remove these entirely would, in addition to marring the appearance, cause future cracking or checking of the decal. A final coat of varnish after application gives added durability.

Applications to rubber may be made in the mold or by cold methods. Any color or design can be reproduced and the label adheres so well that it becomes a part of the product and remains elastic for the life of the part.

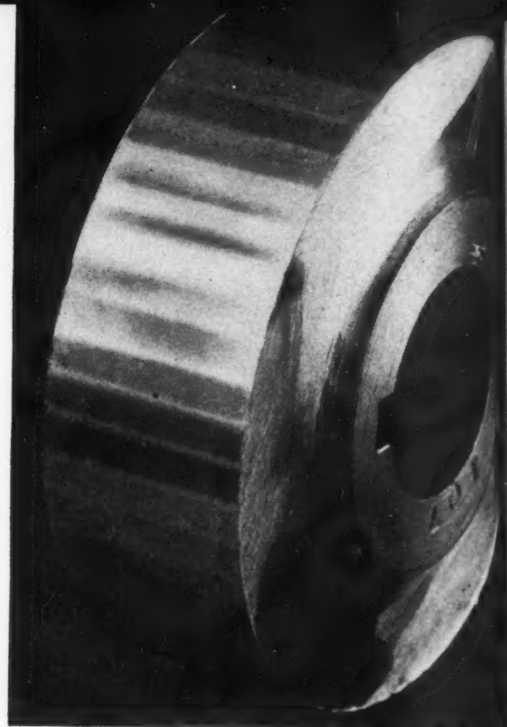
Decals, in addition to being used for data and instructions, are serving a dual function as tamper-proof seals for many enclosures. This application is employed in war plants for sealing a part after inspection. Any subsequent attempt at sabotage would be apparent at once.

Plastic plates and their utility for data plates, instruction plates and nameplates will be discussed in a subsequent article.

Information and illustrations included in this article were supplied by the following companies: American Decalcomania Co., Avery Adhesives, Dura Products, Jaco-Lac Decal, The Meyercord Co., and National Decalcomania Corp.

Latest Findings on Surface Fatigue

By Earle Buckingham
Massachusetts Institute of Technology



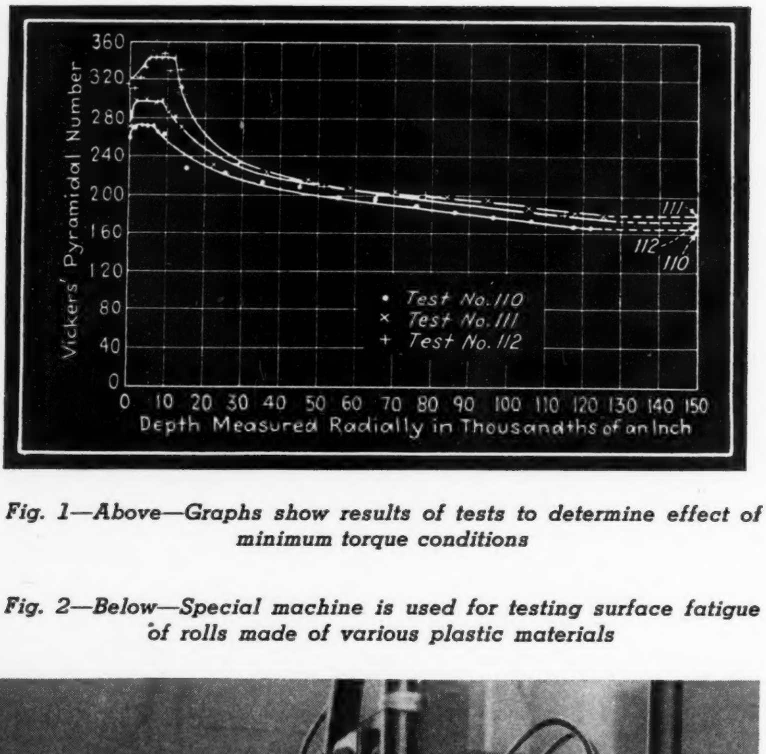


Fig. 1—Above—Graphs show results of tests to determine effect of minimum torque conditions

Fig. 2—Below—Special machine is used for testing surface fatigue of rolls made of various plastic materials

GREATER knowledge of the surface-fatigue characteristics of materials will serve many useful ends. Surface fatigue is a phenomenon largely responsible for the type of wear commonly known as pitting. Definite information will permit the more intelligent and effective choice of materials for specific service conditions. Again, if the surface-fatigue characteristics of the materials used are known and the surfaces of a mechanism are carefully watched, dynamic loads that cause surface failure can be detected before any harm is done to any other part of the mechanism. In addition, a reasonably close measure of load intensity can be made from the condition and appearance of the surface failure on the specific part. Thus, such information supplies a tool, or weighing scale, with which to measure the intensity of existing loads on all types of mechanisms in actual operation, and also makes possible more accurate comparisons between laboratory test results and actual service conditions.

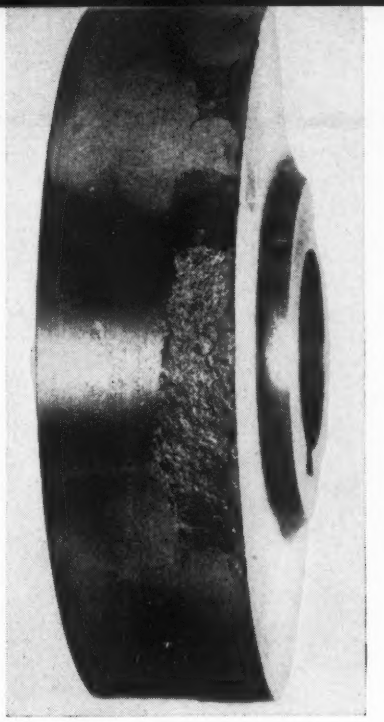
Tests have been run almost continuously during the past six years on a special testing machine, shown in *Fig.* 2. Briefly, the machine consists of two shafts running in plain bearings, one mounted in a heavy fixed frame and the other mounted in a substantial swinging frame. Test rolls, with a maximum face width of one inch and from 2.2 to 4 inches in diameter, are mounted on the shafts. A load

Abstract of a paper presented at the recent New York meeting of The American Society of Mechanical Engineers.

Fig. 3—Left—Machine steel test roll after being run with hardened steel roll under a load of 1940 pounds for 67,800 cycles

Fig. 4—Right—Surface fatigue of nickel-cast-iron test roll after 406,000-cycle run under 3500-pound load with hardened steel roll 2.3 inches in diameter

Fig. 5 — Extreme right — Heat treated nickel-cast-iron roll after run of 400,000 cycles with 3435 pounds of loading



is set up between them by a calibrated spring acting against the swinging frame, and revolution counters are connected to each shaft. Gears may be mounted on the shaft ends in such a manner as to obtain any desired amount of slipping or rubbing between the two test rolls. Most of the tests under rolling conditions have been run without gears, the rolls driving each other by means of the friction between them.

Plain bearings are used to avoid possible dynamic effects of ball or roller bearings and an oil pump provides lubrication for the bearings and gears. The machine is driven by a small Sprague dynamometer and records are kept of the torque input during runs.

Physical properties and structure of the materials under test appear to have a pronounced influence on the nature of surface failure. The following detailed account of the several phenomena that occur concurrently under test conditions of rolling contact pertains only to plastic materials.

Plastic Flow Work-Hardens Surface

The action of one roll upon the other carries a plastic and elastic wave ahead of the contact area between them, setting up conditions quite similar in many respects to those existing when cold-rolling metals. This action cold-works the surface lamina, increasing its hardness and raising the physical properties of the material's surface. Further, this action appears to be progressive, tests indicating that the depth of cold-working (which might well be called "mechanical case-hardening") increases with the number of repetitions of stress up to a maximum depth which probably depends on the pressure. Hardness also increases with the number of stress repetitions as well as with increase of load. However, depth of penetration appears to depend mostly upon the number of repetitions of load.

This increase of surface hardness has been observed on practically all samples of plastic materials tested. Special tests to study this phenomenon were made by E. L. Bartholomew Jr., in 1937, using rolls of 18-8 stainless steel. Three tests, Table I, were run on rolls 2.3 inches in diameter with 1-inch face width against a hardened and ground steel roll of the same size.

Stresses are computed as though loaded under static conditions. Photoelastic tests indicate that, under the combined stress conditions existing in rolling contact, stress distribution is changed and the stresses are greater than those existing under static conditions of simple radial loading. In the absence of more exact methods, conditions are compared on the basis of static radial loading only.

Table I

Test No.	Load, (lb)	Number of Repetitions of Stress	Maximum Specific Compressive Stress (psi)	Maximum Shear Stress (psi)
110	2362	500,000	146,000	44,400
111	2362	2,069,000	146,000	44,400
112	3150	4,940,000	184,000	56,000

On several tests it has been noticed that input torque tends to decrease to a minimum as the test progresses and then to rise slightly after a long period of running under minimum torque conditions. This increase of torque takes place before any indication of destructive pitting can be detected by an examination of the unetched surface. Destructive pitting then occurs one or more million cycles after the increase of torque has been detected. Test No. 112 was run until the torque was observed to rise from a minimum of about 1.9 to 2.06 pounds at a radius of 1 foot. Results of these tests are plotted in *Fig.* 1, showing Vickers hardness numbers against depth in thousandths of an inch below the surface. The dotted lines at the ends of the graphs show core hardness.

It will be noted that the maximum hardness reading is obtained a few thousandths of an inch below the surface and that this depth of maximum hardness is greater for test No. 111 than for test No. 110. It is possible that there is a tendency for the surface material to start disintegrating, perhaps because of the reversed bending action on the surface as the elastic wave travels ahead of

the contact. Microphotographs taken just below the surface show slip lines, indicative of cold-working. In that of test No. 112, the structure had a semblance of having been more severely worked than either of the other two samples, the grains appearing to have been shattered. The structure as a whole showed a general precipitation at the grain boundaries and many slip planes.

With very plastic materials, such as soft steel and brass, under heavy loads, this plastic flow of the surface material results in definite waves or corrugations on the surface, much the same as may be found on gravel roads, particularly on up-hill grades. One possible explanation is that when plastic flow has hardened the material sufficiently, it either stops, or is reduced at that point and the rolls ride over to start building up another wave. Sliding accentuates this condition greatly. Similar waves or corrugations are often found on railroad rails, particularly on curves where sliding between the wheel and rail is greater than on straight stretches.

Shown in *Fig.* 3 is a 3.3-inch diameter test roll of .50 carbon machine steel (substantially SAE-1050) which was run with a hardened steel roll of 2.2 inches diameter under a load of 1940 pounds for 67,800 cycles. Hardness of the core material was 77 rockwell B; that of the wave crests 89 rockwell B, and that of the wave troughs 86 rockwell B.

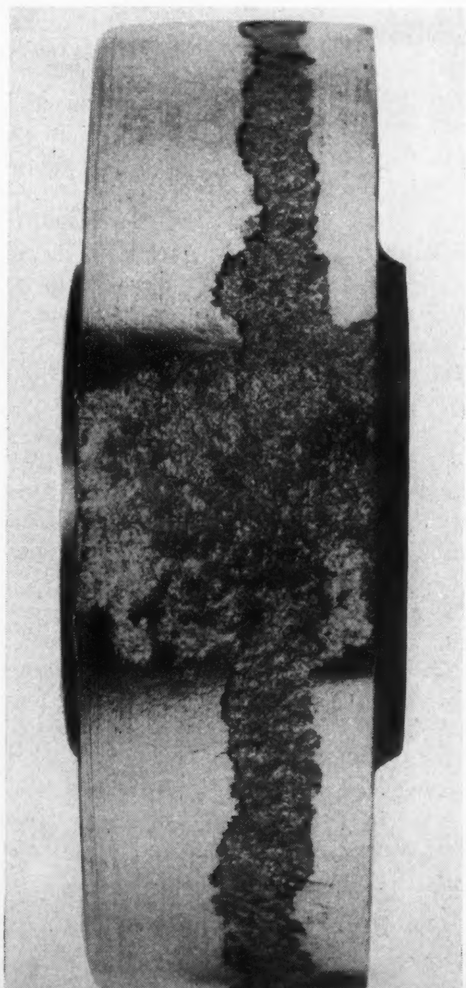
It is believed that the change in torque observed as the test progressed is some measure of the work done in the plastic deformation of test samples. For example, on test No. 112, the initial scale load (at a radius of one foot) shortly after the test started was 3.5 pounds. After about one hour, it had fallen to 2.3 pounds. After 24 hours continuous running, it had fallen to 2.25 pounds. Then it showed a continuous decrease to 1.9 pounds at the end of about four million cycles before it started to rise again to 2.06 pounds when the test was stopped for examination of the surface material structure. The first reduction of from 3.5 to 2.25 pounds was largely due to the influence of warming up the testing machine, while the further reduction of torque is believed to be a measure of the plastic working. When the torque has reached a minimum and continues there without further change, it is felt that this is reliable evidence of the material having been cold-worked to its limit under the specific test conditions. Any deformations, other than those resulting from failure of the material, are considered to be elastic ones only.

Influence of Elastic Deformation

At the same time the surface lamina is being cold-worked by the plastic flow, and even after the surface has been cold-worked to the limit, the elastic wave traveling ahead of the contact imposes reversed bending conditions on this surface lamina. The result appears to be, in many cases, development of microscopic cracks at right angles to the direction of rolling. Microscopic examination of the stainless-steel samples showed evidence of surface material disintegration at the grain boundaries.

Incidentally, the number of stress cycles required to establish the surface-endurance limits is very much greater than the number of cycles required to establish the flexural or bending-endurance limit. Where, in general, from one to five million cycles will establish the flexural-endurance limit of the softer steels, from twenty to thirty million cycles appear to be necessary to establish the surface-endurance limit.

Tests have been run in some cases to twenty-five or thirty million cycles without any surface indications (without etching) of destructive pitting, and the test has then been stopped. To make sure that the material is still sound, a light lathe cut has been made on the surface. In some cases, the material has crumbled away in front of the cutting tool, showing disintegration of the surface material, although it was not evident from a careful ex-



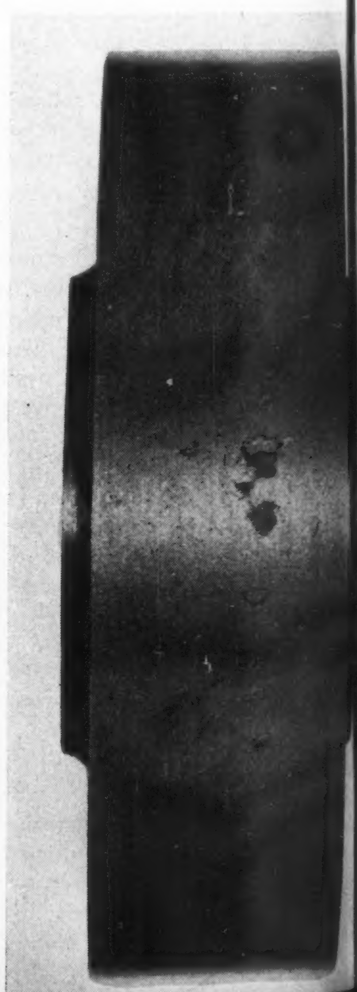
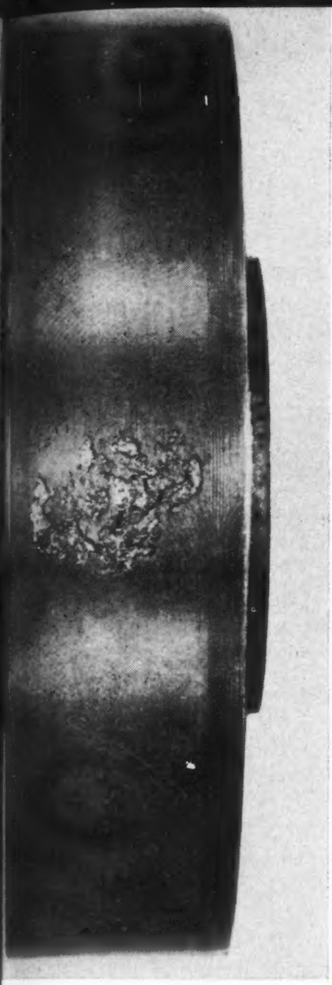


Fig. 6—Right—Chrome-nickel-cast-iron roll after run of 661,000 cycles under 2500-pound load

Fig. 7—Extreme right—Result of 13,090,000-cycle run under 1500-pound load on chrome-nickel-cast-iron roll 3.7 inches in diameter



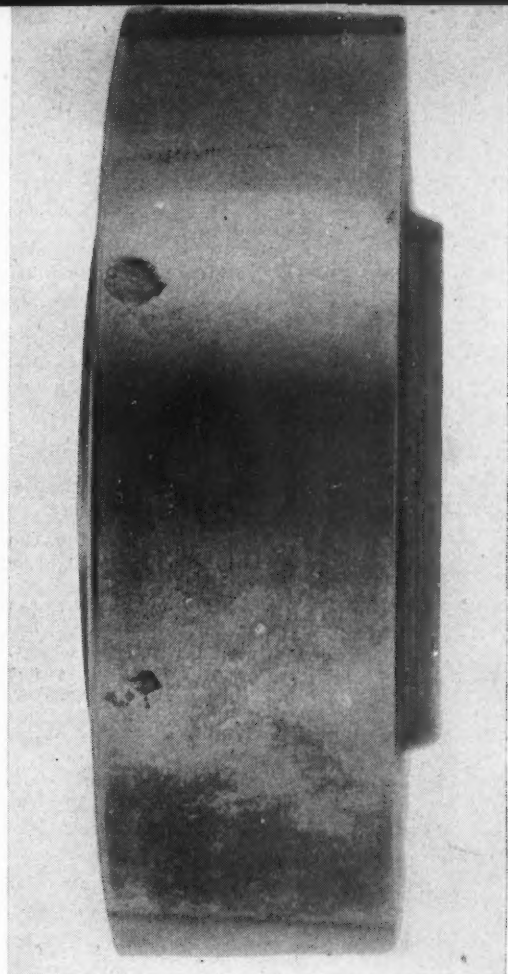


Fig. 8—Extreme left—Phosphor-bronze roll after run of 1,125,000 cycles under load of 3500 pounds

Fig. 9—Left—Result of 808,000-cycle run under 4750-pound load on machine-steel roll

amination of the surface. In other cases, a clean chip was obtained, which indicated that the surface material was still sound, yet the appearance of the surfaces which gave either types of chip conditions appeared to be the same.

Small pits are evident on the surface in all cases where the loads are appreciable, whether the stresses are above or below the surface-endurance limits of the material. These pits are shallow, possibly up to .005-inch deep at most, generally much less, and the shapes appear to depend upon the material structure. Some are microscopic, only a few thousandths of an inch across; others are one sixteenth of an inch or more and of irregular shapes. This we have called "incipient pitting." Various explanations have been suggested to account for this phenomenon. Dr. Stewart Way[†] ascribes it to the formation of microscopic surface cracks followed by the penetration of oil which lifts these small sections out because of the hydrostatic pressure developed at the region of contact. It has also been called "corrective pitting" and ascribed to the high local pressures developed on the ridges or peaks of surface irregularities left by the cutting tool. Again, it has been suggested that the plastic flow of the surface lamina builds up local shearing stresses which shear these particles out after the surface cracks appear. Possibly any or all of these explanations may be true, depending upon the conditions and nature of the material. At all events, this incipient pitting does not appear to be the cause of any great concern. If loads are below the surface-endurance limits, incipient pitting appears to progress to a certain extent and then to cease. It is our belief that the elastic wave traveling ahead of the contact is a contributing factor to this phenomenon.

Destructive Pitting

Simultaneously with the foregoing phenomena, and probably with many others not yet observed, shear stresses are repeatedly imposed upon the material below the surface. When the loads imposed develop stresses beyond the surface-endurance limits of the material, particles or flakes will be sheared out of the surface of the material. Thus far in these tests, with very few exceptions, the thickness of these flakes or the depth of the pits has been equal to or greater than the depth to the point of maximum shear.

In tests on the softer and more plastic cast-iron alloys, large flakes sheared out of the surface, some one quarter of an inch wide and as much as one inch in length. On the harder heat-treated cast-iron alloys, these flakes were sometimes as small as one-eighth of an inch and of irregular shape. These flakes varied in thickness from about .01 to .035-inch, depending largely on load intensity and number of cycles. *Fig.* 4 shows the surface failure of a 4-inch diameter test roll of nickel cast iron, running with a 2.3-inch diameter hardened steel roll under a load of 3500 pounds at the end of 406,000 cycles.

Unless otherwise noted, all tests were run against a hardened steel roll of 2.3-inch diameter. *Fig.* 5 shows a heat-treated nickel-cast-iron roll, 341 brinell hardness number, 3.8-inch diameter after a run of 400,000 cycles under a load of 3435 pounds. The flakes measured from .033 to .036-inch in thickness.

A chrome-nickel-cast-iron roll 3.7 inches in diameter after a run of 661,000 cycles under a load of 2500 pounds, is shown in *Fig.* 6. *Fig.* 7 shows another roll of the same size and material after a run of 13,090,000 cycles under a load of 1500 pounds.

Shown in *Fig.* 8 is a phosphor-bronze roll, 4 inches in diameter, after a run of 1,125,000 cycles under a load of 3500 pounds.

A machine-steel roll (substantially SAE 1020), 3.5 inches in diameter, is illustrated in *Fig.* 9 after a run of

[†]Research Engineer, Westinghouse Electric & Manufacturing Company, Research Laboratories, East Pittsburgh, Pa.

808,000 cycles under a load of 4750 pounds. The original hardness was 22 rockwell C, and the surface hardness at the end of the test had increased to 32 rockwell C.

These illustrations show some of the different types of destructive pitting; on some, the shallow cavities left by the incipient pitting may be seen. There does not appear to be any connection between the incipient and destructive pitting.

Exact sequence of the different phenomena is a matter of question. Probably in some cases a crack may start under the surface in the region of high shear stresses before disintegration of the surface material progresses far. This appears to be the case with phenolic-laminated materials and brass. In other cases, the reverse may be true. Again, both types of failure may progress together. Probably the specific physical characteristics of the materials influence these conditions.

Tests On Cast-Iron Alloys

To date, the most extensive series of tests has been on several cast-iron alloys. All of these tests, unless otherwise noted, were with rolls 1-inch in face width running with a hardened-steel roll 2.3 inches in diameter. The first test rolls were 4 inches in diameter and were turned down after one test and used again in a succeeding test. Here it was noted that the surface material crumbled away ahead of the cutting edge of the tool, so the diameter was reduced until the nature of the chip indicated sound material. Some of these test results indicated that the properties of the material might be changing as the roll diameter was reduced more and more from its original size. Therefore, on later tests, the rolls were cast to a size to finish 2.3 inches in diameter. To save time, particularly after it became evident that the tests must run to thirty million cycles or more to establish the surface-endurance limits of these materials, the smaller rolls were used to permit higher speeds of the test disks within the same range of surface velocities as before.

Representative test results are given in TABLE II. Actual test data are given first, followed by the equivalent load (based upon static-stress conditions) on a 4-inch diameter test roll and the equivalent brinell hardness number for purposes of comparison.

TABLE II
Results of Tests on Cast Iron with Steel Scrap (Semisteel)

Test No.	Roll Diam.	Load (lbs.)	Hardness Core	Hardness Surface	Thickness of Flakes	Number of Cycles	Equivalent Load 4-in. Roll	Equivalent Brinell Core	Equivalent Brinell Surface
32	3.5*	3330	22-C	24-C	....	173,000	3620	240	248
47	3.8*	3435	96-B	102-B	.012/.014	279,000	3500	216	256
131	2.3	2362	190	209	.013	300,000	3000	190	209
48	3.8*	2940	95-B	98-B	....	400,000	3000	210	228
129	2.3	1968	180	190	.007	1,330,000	2500	180	190
128	2.3	1575	....	....	.010	2,093,000	2000	...	
18	3.7*	1720	26-C	30-C	....	1,920,000	1770	260	283
126	2.3	1181	....	....	No Failure	32,530,000	1500	...	
125	2.3	1024	....	....	No Failure	36,240,000	1300	...	...
17	3.7*	1210	94-B	97-B	No Failure	6,499,000	1245	205	222

*Turned down from original 4-inch diameter after earlier tests.

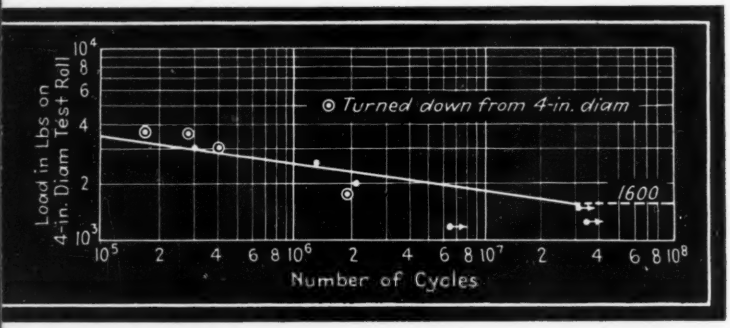


Fig. 10—Logarithmic chart, showing graph of test results which are listed in Table II

Test results given in the table apply to gray iron with 30 per cent steel scrap, sometimes known as "semisteel." The chemical analysis of a sample of this material is as follows: Silicon 1.84; sulphur .136; manganese .65; phosphorus .387; total carbon 3.25; graphite 2.8; combined carbon .45.

Results of physical properties tests on this material are shown in TABLE III.

Heat-treatment (tests Nos. 18 and 32) was as follows: Heat to 1500 degrees Fahr., and quench in oil; draw to 950-1000 degrees Fahr.

As none of the samples under rolling contact failed after 30,000,000 cycles, the intersection of the line representing load against number of cycles on a logarithmic chart (*Fig.* 10) with the 30,000,000-cycle point has been used to estimate surface-endurance limit. Thus, the surface-endurance limit of this material has been estimated as between 1500 and 1600 pounds load on a 4-inch diameter test roll of 1-inch face width in rolling contact with a hardened-steel roll of 2.3 inches diameter. The equivalent maximum specific compressive stress, on the basis of static-stress conditions of load, is equal to 87,500 pounds per square inch.

TABLE III

Property	As cast	Heat-treated
Ultimate strength (psi)	35,200	45,950
Elastic limit (psi)	15,000	35,750
Brinell hardness number	223	255
Flexural endurance limit (psi)	21,000	25,000

Although the complex behavior of plastic materials under repeated surface stresses set up by rolling and sliding is still far from being fully understood, and actual intensities of the several stresses—compressive, tensile and shear—are thus far indeterminate, the actual test-load re-

(*Continued on Page* 248)

What's a Good Yardstick for Patentability?

By George V. Woodling

MUCH confusion now exists resulting from the lack of uniform patent decisions, which in some instances appear to be based more upon the matter of feeling rather than of logic. The adoption and application of a uniform "yardstick" of invention, recently advocated by the Patent Planning Commission, will constitute a major advance in the field of patent law and probably will do more to improve the patent system than any other single piece of legislation.

While it is clearly evident that measurement of the standard of invention cannot be expressed in numbers,

I OFTEN SAY that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of science, whatever the matter may be

—Lord Kelvin

nor can it ever be reduced to the stage of science, yet the attempt to create a scale for patentable invention may be the beginning of a new era in patent thinking. The legislation will be of the type which sets forth a declaration of national policy, giving guidance to both the Patent Office and the courts when passing upon the question of invention. It will be more like a radio beam guiding an airplane through the sky than an engineering formula. By giving general direction to patent cases it will discourage the handing down of spotty and random decisions which lead to confusion. As pointed out by the Patent Planning Commission, the declaration of national policy should require the Patent Office and the courts to place more stress upon whether the new device in question has contributed to the advancement of the art.

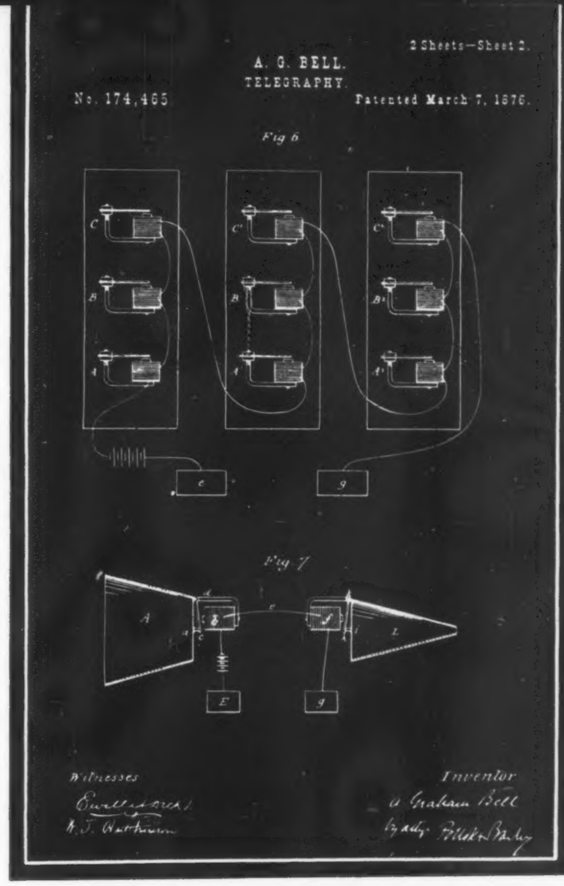


Fig. 1—Importance of granting patents for inventions of an apparently trivial nature is illustrated by Alexander Graham Bell's original telephone patent, which was hardly more than a toy

Effort will be made to seek the real gist of the invention rather than simply to compare its mechanical structure with some prior patent to ascertain the improvement. If the new device is simply structurally different without being functionally different from the prior art patents, that will not be enough to merit the award of the patent. The following language taken from a court decision, relating to a bottle stopper seems to point in the right direction:

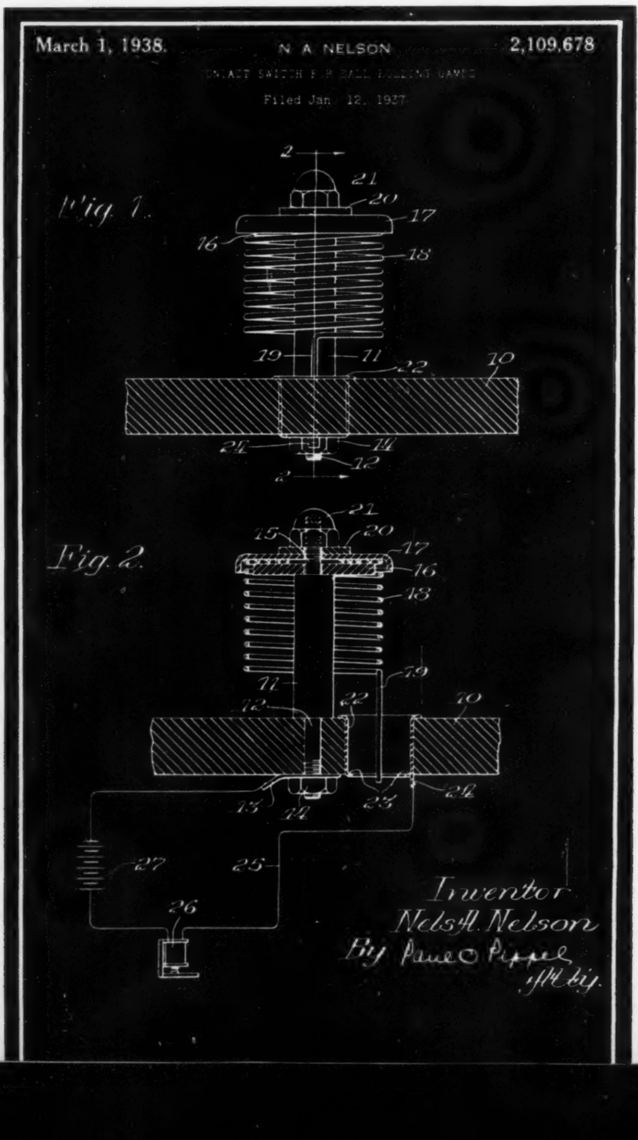
> "It does not follow that the inventive idea is the same because each employed a metallic element and an elastic element to accomplish the same purpose; for, if terms are employed which avoid defining the distinctive character of the device or imperfectly describe it, few patents would escape being declared invalid, for nearly all employ the same elements. The imagination may find in the disk of sheet metal of the old device, the cup-shaped disk of the new design, for men are prone to see what they want to see. Polonius saw in the cloud first a camel, then a weasel, and then something 'very like a whale,' as Hamlet bade him. Taught by the new device, we can see that a 'disk of sheet metal' may be converted to a purpose altogether different from that which the old device used, not by a mere mechanical change, but by a functional change, which constitutes invention due to a conception of a different plan."

Under a national plan, where patentable invention is measured in the light of "functional change" rather than mere "mechanical change", it is to be observed that such

a policy does not exclude the patenting of things which are trivial. It makes no difference whether the invention relates to a small device or to a large piece of machinery or apparatus. Both are treated alike, so long as they advance the art. Without mature study or analysis, some persons may conclude that a policy which grants patents on apparently trivial things is all wrong. The difficulty with a policy which would exclude the protection of trivial things is that no judge or patent examiner, or any one else, possesses such a master mind that he can predict with 100 per cent accuracy whether a trivial thing will always remain a trivial thing. Some of our greatest and most basic inventions had trivial births. Note the following quotation which was made by our present Commissioner of Patents in discussing Bell's patent, *Fig.* 1, covering the telephone:

> "I refer to that specifically in order to call your attention to the crude character and simplicity of a so-called basic invention and to show you the many refinements that are necessary to convert a basic invention into a commercial enterprise.
>
> "The second thing about the Bell patent I wish to mention is its extreme simplicity and almost triviality. If the Patent Office at that time had adopted that high standard of invention which excludes all things trivial, it would probably have refused the patent to Bell, since in its basic characteristics it is hardly more than a toy which would fail to amuse a very young child."

Fig. 2—This switch was designed for use on a pin-ball machine. In referring to it, one judge declared: "To call the device here an invention or discovery . . . is, in my judgment, to degrade the meaning of those terms"



Our present system, which gives encouragement to the protection of new things even when at the time of patenting they may appear to be crude, should be continued. This leaves the door open for the protection of those pioneer inventions which invariably are born without refinement and practicability. The continuance of the principle may well be justified on the single ground that out of all the crude and simple inventions, notwithstanding the "know-all" negative valuation cast upon them by the critical public, one may turn out to be commercially important. Witness what Robert Fulton wrote about the critical indifference of the public against his steamboat:

> "When I was building my first steamboat, the project was viewed by the public either with indifference, or with contempt, as a visionary scheme. My friends, indeed, were civil, but they were shy. They listened with patience to my explanations, but with a settled cast of incredulity on their countenances. As I had occasion daily to pass to and from the shipyard while my boat was in progress, I often loitered unknown near the idle groups of strangers, gathering in little circles, and heard various inquiries as to the object of this new vehicle. The language was uniformly that of scorn, sneer, or ridicule. The loud laugh often rose at my expense; the dry jest; the wise calculation of losses and expenditures; the dull but endless repetition of Fulton's folly. Never did a single encouraging remark, a bright hope, a warm wish, cross my path. Silence itself was but politeness, veiling its doubts, or hiding its reproaches."

When the courts or the Patent Office gage invention in the light of its "functional change", testing whether it has advanced the art, there is no need to resort to the practice of judging whether a thing is trivial or impractical, as attempted by a Supreme Court Justice when rendering an opinion involving the patentability of an electrical switch for a pin-ball game, *Fig.* 2. The switch was so disposed on the board as to serve as a target which, when struck by a freely rolling ball, would momentarily close an electrical circuit. In rendering a minority opinion, he stated in part:

> "There can be no infringement of a void patent, and a patent which shows neither invention nor discovery is void. . . . .
>
> "The Constitution authorizes the granting of patent privileges only to inventors who make discoveries, and the statute provides for the granting of patents only to those who have invented or discovered something new. *To call the device here an invention or discovery* such as was contemplated by the Constitution or the statute is, in my judgment, to degrade the meaning of those terms."

The switch probably found its most immediate use in connection with pin-ball rolling machines. But, who knows, the same switch or the principle embodied in it might later be found to be highly useful in, for example, a remote trigger control for releasing bombs. Had the Bell patent been shown in "low environment" such as in connection with a pin-ball machine, and judged in the light of the above quotation, the patent might well not have been issued to Bell.

It is to be observed that the "flash of genius" test, which is applied by some judges and against which much criticism has been directed in recent months, no longer would be used as a test of invention. The gaging of invention by the flash of genius test excludes the protection of most of the inventions made in industrial research laboratories by trial and error, whereas the "functional change" test would not. With the latter test, it would make no difference whether the device in question is simple or complicated, whether it was made by accident, by long, laborious thought, or by an instantaneous flash of mind.

It is believed that the judges who have been resorting to the flash of genius test would willingly and readily conform to the new proposed legislation, when enacted by Congress. In fact, some of the decisions which uphold the flash of genius test may be interpreted as encouraging the adoption of the new proposed legislation as noted in the following quotation, which refers to a molded phenolic distributor part, *Fig.* 3:

> "This block was apparently the result of an intensive study by the plaintiff's engineers. . . . .
>
> "They made and tried out a great many different forms, and came down at last to that which seemed to stand up the best. At least there is no evidence that any higher abilities were demanded than intelligent, well-trained and persistent experiment, acting in the light of the defects which past experience had developed. *Perhaps such qualities are as well worth a patent as sudden flashes of genius; perhaps, indeed, in the long run they are more deserving; but the prize does not go to success so achieved.*"

If patent decisions could be kept in line with a national policy which charts a course, the Patent Office and the courts would be brought closer together in their views, eliminating a great deal of the current criticism that the Patent Office is more lenient in granting patents than the courts are in sustaining them. In the Patent Office the question of invention is passed upon by several hundred examiners as new applications are filed and prosecuted. In the courts the question of invention is passed upon by the judges of substantially one hundred district courts, eleven circuit courts of appeals and the Supreme court. Altogether there are approximately one thousand individuals who may be called upon to determine the question of invention. With such a large number of examiners and judges, the need for a national policy to keep their views in line becomes apparent. At the present time there is no procedure whereby the views of the Patent Office and the views of the Courts may be brought closer together. That is to say, when the Patent Office has once issued the patent upon which suit is later filed in court, there is no legal procedure through which the Patent Office may be called in during the trial of the case to aid the judge in rendering his opinion.

In the adjudication of the patent before the court, new facts and new evidence unknown to the Patent Office invariably are presented by the defendant to show that the patent is invalid upon the ground that the device does not constitute invention. If, during the prosecution of the application, the Patent Office had had knowledge of the new facts and evidence presented in the trial, then the examiner might not have issued the patent. In order to give the Patent Office an opportunity to revise and reexamine the question of invention in the light of the newly discovered evidence, the Patent Planning Commission has recommended that "whenever the validity of a patent is attacked in an infringement suit before a district court the court shall certify the record to the Patent Office for a report on the validity of the patent. The report of the Patent Office as to the effect of the court record upon the validity of the patent shall be advisory only".

The court record comprises the transcript of the entire case, including the drawings, exhibits and copies of all documents and prior art patents. Upon receiving the record, the examiner would study it as if he were acting upon a new patent application to determine whether, in the light of the new fact and evidence submitted in the trial of the case, the patent is valid. The examiner then submits his report to the trial judge who may use it when deciding the case. Generally, a judge lacks engineering knowledge and experience. On the other hand, substantially all of the examiners have had basic training in engineering. The two would tend to supplement each other whereby their joint effort would produce better decisions, particularly so where both were guided by a national policy requiring the measuring of inventions by the "functional test" which awards the grant of a patent for things which advance the art.

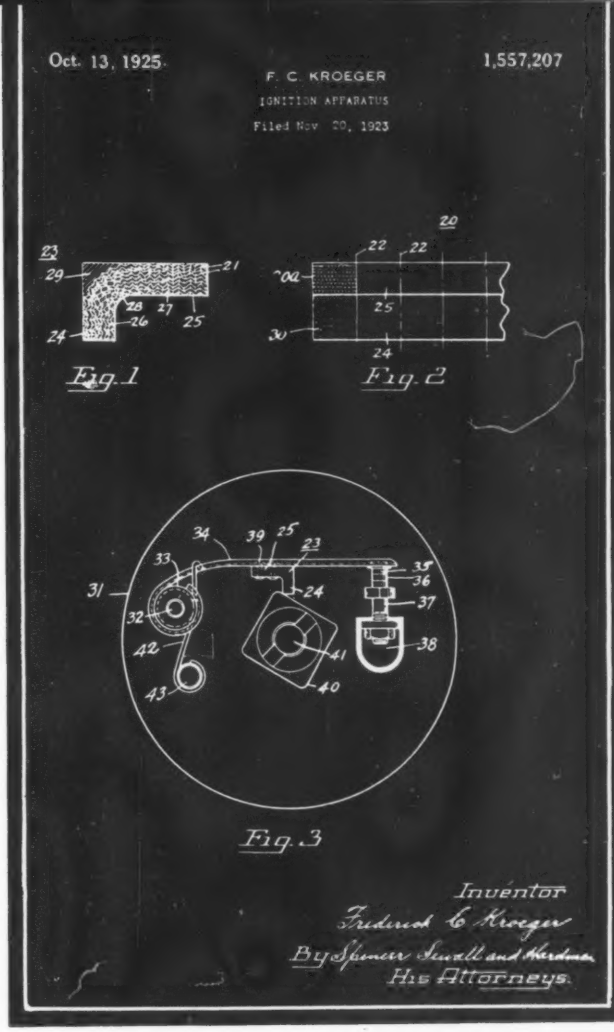
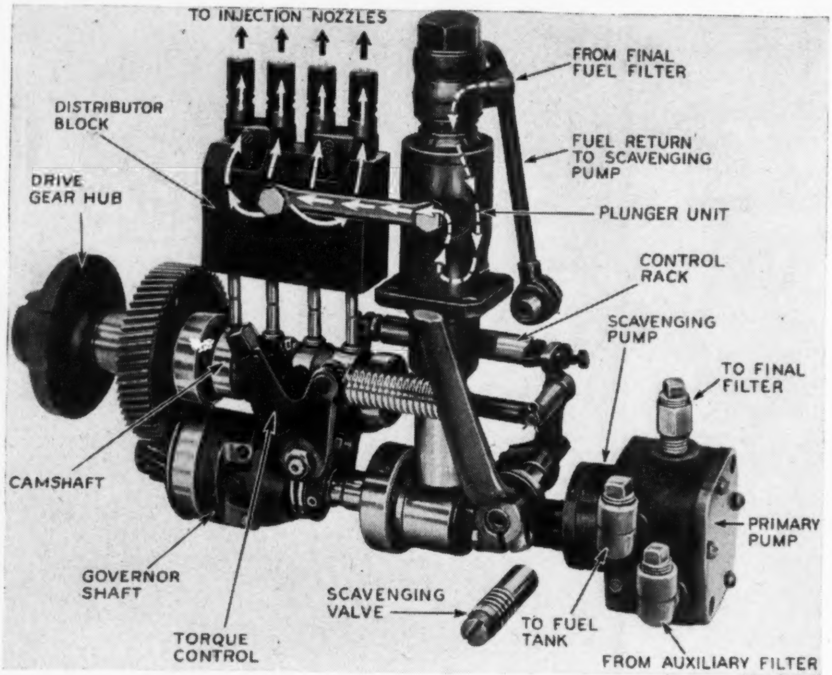


Fig. 3—Design of distributor part, the result of persistent experiment, was not held to be patentable when judged by the "flash of genius" test. Court decision, however, recognized that by other standards such an invention might be worthy of a patent



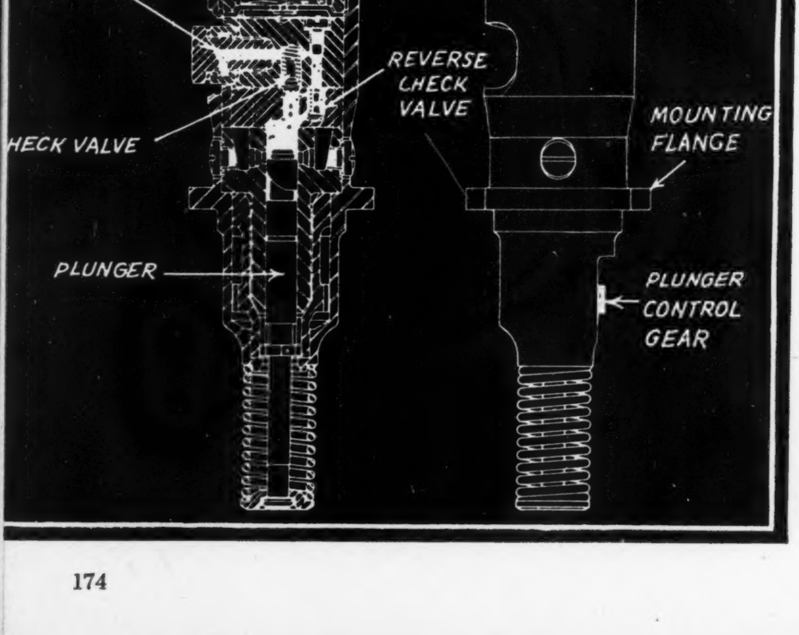
Designing

By Raymon Bowers and R. E. Peterson

International Harvester Co.

Fig. 1 — Above — Skeleton view of pump mechanism. Housing is not shown

Fig. 2—Below—Conventiona helical-grooved plunger operates in two-port barrel



TODAY injection equipment is available to cover any normal demands but at the time the International Harvester company first considered the manufacture of diesel engines such was not the case. Therefore, almost of necessity, both the injection system and the engine were developed together.

For the low engine speeds prevailing, the first injection pump designed was satisfactory. However, demands for increased engine speeds and a wider range of engine sizes soon put injection requirements beyond the scope of this original pump, and it became necessary to consider a new design. Demands called for an injection pump relatively small in size, low in cost and adaptable to a considerable spread of engine sizes and speeds. It was also necessary that the pump be serviceable and capable of handling a variety of diesel fuels.

A thorough study was made of various injection-system types before establishing the basic design believed best suited to meet requirements, and a decision was finally made to concentrate efforts on a single-plunger pump for four-cylinder engines. There were three basic reasons for selection of the single-plunger type of pump: (1) It simplified construction through elimination of three precision plungers and barrels; (2) it eliminated the difficult job of building and adjusting four plungers so that each would deliver exactly the same amount of fuel per stroke at all operating speeds and fuel settings; (3) it simplified the governor problem by reducing the amount of work imposed on it.

Flange-mounted on the crankcase front cover, the single-plunger pump, (see skeleton view of pump mechanism, *Fig.* 1) is completely enclosed and driven by a gear on the pump camshaft. A single plunger meters and delivers all the fuel to the engine through a distributing system consisting of four cam-operated distributor valves. The manner in which fuel is metered and delivered is basically the same as in a conventional multiplunger pump except that the single plunger delivers all the fuel. Governing is controlled by a flyball governor through a simple linkage which rotates the plunger in its barrel. The plunger unit, the distributor unit, the primary and scavenging pump assembly and the mounting flange by which the pump is attached to the engine—and in which the camshaft and

Abstract of a paper presented at the recent War Engineering Annual Meeting of the Society of Automotive Engineers in Detroit.

gle-Plunger Injection Pump

governor shaft gears are enclosed—are all mounted on the pump housing. Camshaft, governor shaft, governor fork shaft, distributor valve tappets and other essential parts are installed within the pump housing.

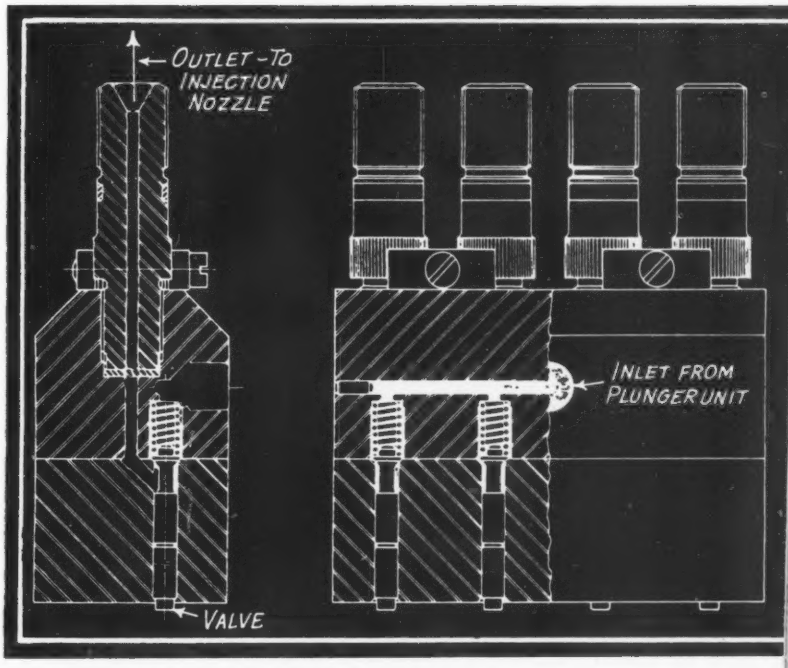
Included in the plunger unit (see *Fig.* 2) are: A single conventional helical-grooved plunger, operated in a two-port plunger barrel by an eccentric on the governor-shaft end; a check and reverse-check valve above the plunger; a by-pass valve on the primary fuel side, and other parts to make it a complete assembly. This unit is located at the top of the pump housing.

Shown in *Fig.* 3, the distributor valve-block assembly holds the four valves which distribute the fuel to the various cylinders. This unit is mounted on top of the pump housing, in front of the plunger unit, and is connected to it by a high-pressure pipe.

A primary pump and a scavenging pump of conventional gear type are assembled as a complete unit in the same housing at the rear of the main pump body and are driven by a common shaft. The primary pump, by means of a pressure-regulating valve, maintains practically constant pressure on the supply fuel at all speeds and loads. The scavenging pump returns to the supply tank all fuel by-passed at the metering assembly and the leakage fuel which escapes past the plunger and distributor valves. In connection with the scavenging pump, there is also a scavenging valve (*Fig.* 4) which is installed in the leakage passage in the main pump housing. This valve automatically opens when the pump is in operation, permitting leakage fuel to be returned to the fuel tank, and automatically closes when the pump is not in operation, preventing fuel from the supply tank backing up and flooding the pump sump.

Driving the governor shaft and operating the distributor valves, the camshaft is installed in the top of the main pump housing and extends through the pump flange which is mounted on the front end of the pump housing. Installed in the main pump housing beneath the camshaft, the governor shaft carries the governor weight assembly, operates the plunger by means of an eccentric, and drives the primary and scavenging pumps. It is driven at four times the camshaft speed.

Operation of the primary fuel-supply system, shown



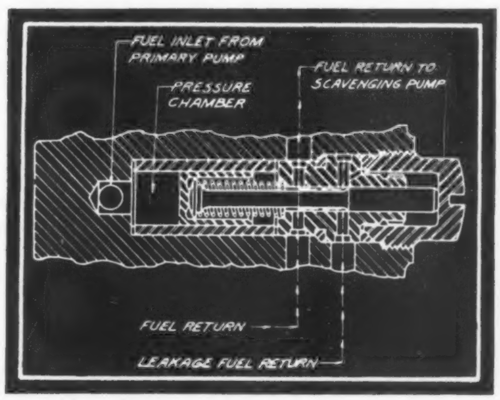
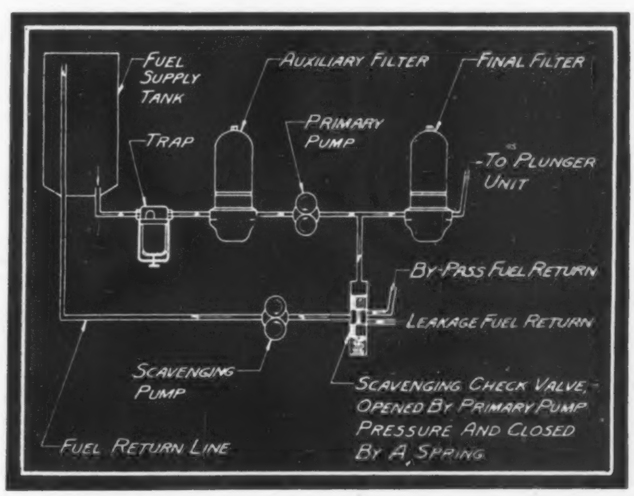


Fig. 3 — Above — Distributor valve-block unit apportions fuel to various cylinders

Fig. 4 — Right — Scavenging valve opens automatically when pump is in operation and vice versa

Fig. 5 — Below — Schematic diagram of primary fuel-supply system



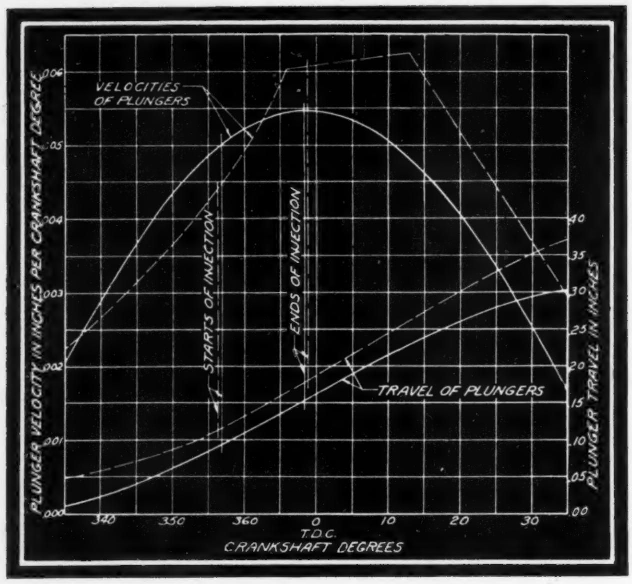


Fig. 6—Plunger "velocity" and "travel" curves of I.H.C. and conventional type injection pumps

schematically in *Fig.* 5, is as follows: On leaving the supply tank, the fuel passes through a trap which removes water and coarser particles of foreign matter. From the trap the fuel goes through an auxiliary filter element, where additional filtration takes place, and then through a filter screen at the inlet to the primary pump. It then passes through the primary pump where it is put under light pressure and on through a final filter element and into the plunger unit assembly. Here it goes through a second filter screen before passing into a reservoir surrounding the ports in the plunger barrel. This amount of filter equipment may seem to be more than is necessary to those not familiar with the dirt conditions encountered in tractor operation. However, experience has shown that the dirt hazard, even under what most operators consider good fuel-handling conditions, is a serious problem. There is a pressure-regulating valve in the primary pump which maintains practically constant pressure on the supply fuel at all times. This is accomplished through by-passing all fuel not required by the engine or by-passed at the plunger unit, back into the primary pump inlet.

Operation of Plunger Unit

In the plunger unit, (*Fig.* 2), primary pump pressure charges the chamber above the plunger when the ports are uncovered. To obtain uniform charging of this chamber at all speeds and fuel settings, it was necessary to introduce a by-pass valve in the fuel supply system. This by-pass valve is located at the top of the plunger unit, and the by-passed fuel is returned to the scavenging pump and thence to the supply tank. After the chamber above the plunger has been charged and the plunger is starting its upward travel, a cam raises a distributor valve (*Fig.* 3) which opens a direct passage between the plunger unit and a nozzle in the cylinder head.

Injection starts when both ports of the plunger barrel have been covered by the plunger, the check valve above the plunger raised off its seat, and the fuel put under sufficient pressure to open the nozzle valve. Because of a ⅛-inch helix running half way around the top of the plunger and on the side opposite from the helix which ends injection, one port starts injection, and the other ends injection. When the lower helix on the plunger uncovers its port, injection ends, and the check valve above the plunger returns to its seat. To prevent fuel dribbling from the nozzle after injection ends and causing exhaust smoke, a reverse-check valve is built into the check valve assembly above the plunger. This reverse-

(*Continued on Page* 238)

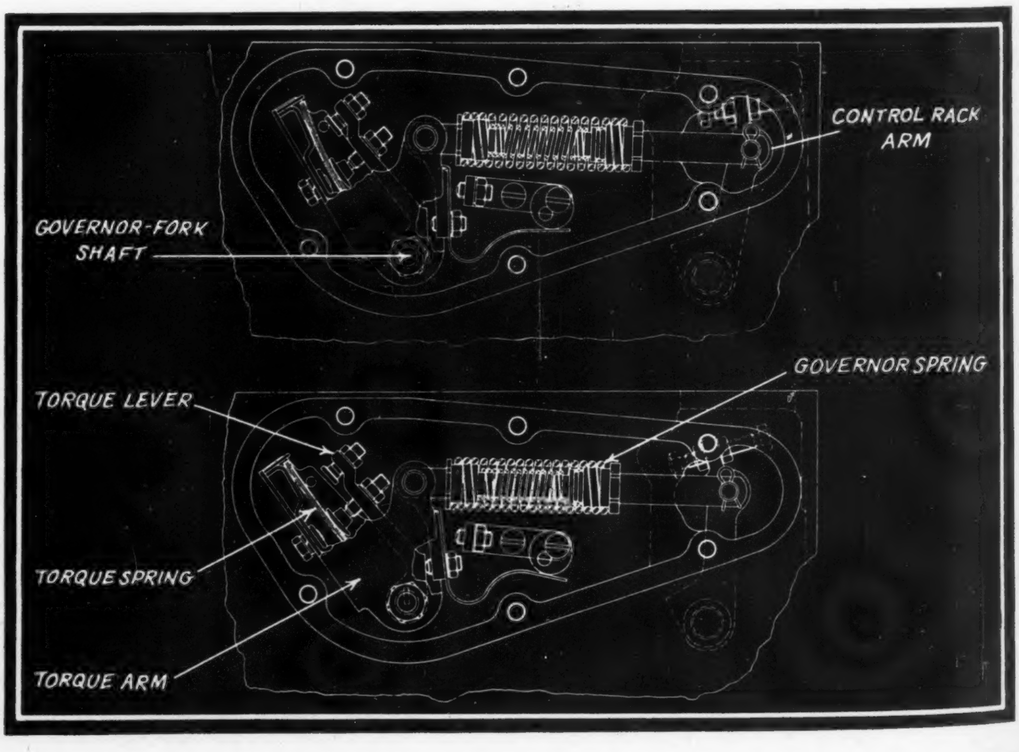


Fig. 7—Torque-control unit utilizes combination of flat and helical springs. Upper view shows high-idle setting. Lower view shows setting for 700-revolutions-per-minute idle position

MACHINE *Editorial* DESIGN

Time's Not Up Yet!

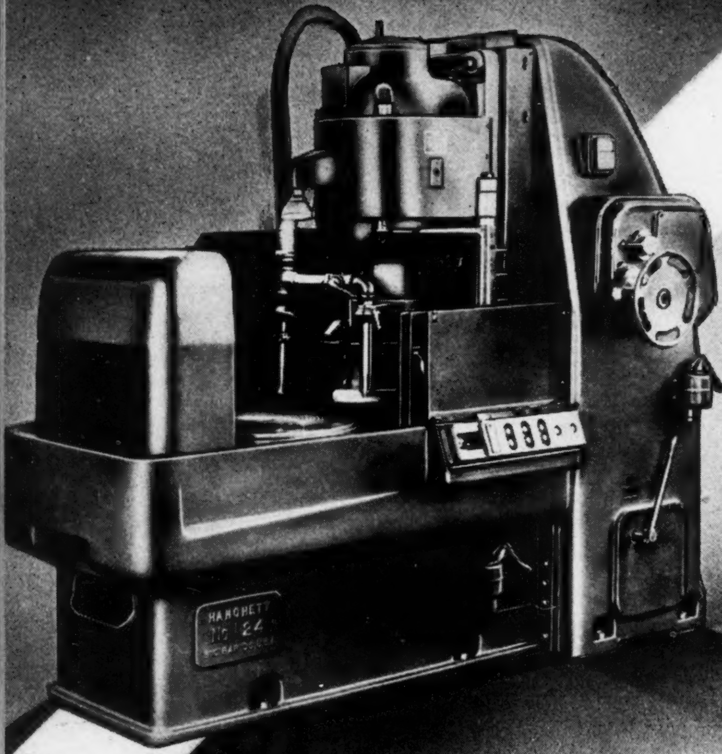
ENGINEERS responsible for design have good reason to recall that February 11 marks the ninety-seventh anniversary of the birth of Thomas A. Edison. The discoveries of this great inventor, though primarily of a peacetime nature, are playing a momentous part in the current world conflict. His electric light, for example, might well be considered the basis for the electronic tubes which constitute the heart of the radar equipment so vital to the progress of the United Nations at this time.

That the Edison tradition of discovery and development still lives on is well exemplified by the current outstanding progress in the art of jet-propulsion flight. Though propellerless planes are at present being developed and tested as implements of war, the science of flight by this method unquestionably will reach a stage, by the end of the conflict, at which it will exert a far-reaching influence on the future of aviation.

Edison's skill and untiring energy—he is said to have been satisfied with four hours sleep out of every twenty-four—are finding their counterpart in the work of many another designer at this time. Engineers working on all types of wartime devices ranging from the radar equipment just mentioned to the lowly yet effective bazooka—the operation of which is allied to some extent with the jet-propulsion flight of planes—have labored with patriotic zeal to put this country ahead. When the detailed stories of the work of designers during the war can be told, it will surely be seen that their achievements—even though lacking the glamour of some of the individual successes of the old master—are destined to play an equally vital part in future progress.

According to the change in thought as to the eventual length of the war, it is still not too late for further development. Timeliness—as Leonardo da Vinci learned and Edison knew—is the essence of successful invention and design. Now is the time for American designers to redouble their efforts in utilizing to the utmost advantage the period that may be necessary to achieve complete victory.

L. E. Jermy



Left—Employing electrically-driven screw feed for traversing its rotary magnetic chuck, surface grinder made by Hanchett Manufacturing Co. has direct drive on grinding-wheel head operated by push-button control. Careful balancing of rotating parts keeps vibration at a minimum

Above—Combin
combustion tube fur
Engineering Co. em
platinum thermocou

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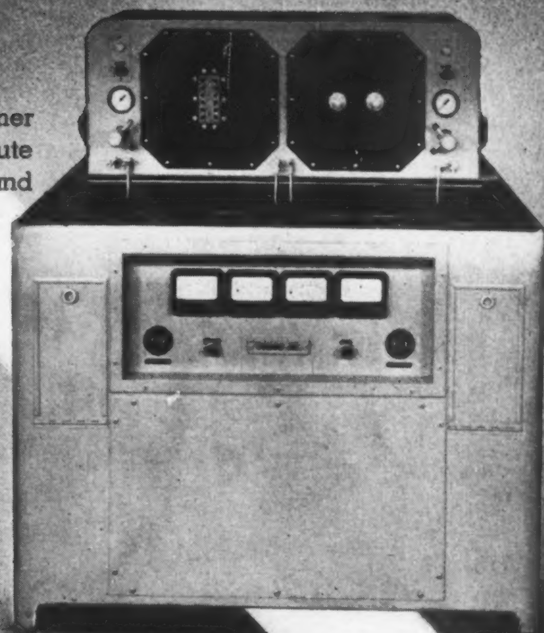
Right—Jaws and jaw holder of starter test stand made by Airplane Mfg. and Supply Co. are heat-treated SAE 4140 steel. When testing, torque is transmitted by torque-arm yoke to hydraulic piston, forcing glycerin to hydraulic gage on which torque is read directly in foot-pounds

Left—Featuring streamline design, new dry-type transformer made by General Electric employs case of sheet steel finished in two-tone gray. Accessibility of interior parts is facilitated by readily removable end and side panels

Above—With pinions mounted on squ
52100 steel, considerable space saving
National Cash Register's new payroll ma
ous mechanism combining internal and

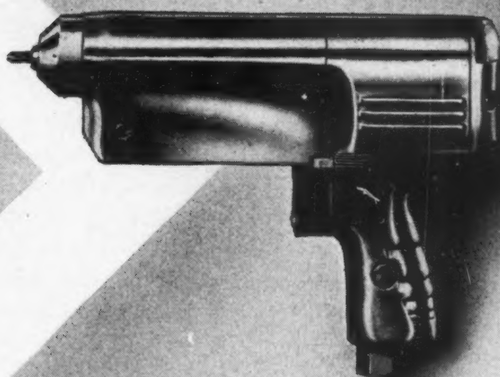


Right—Employing a motor-driven timer scaled to fractional parts of a minute for precise governing of heating and quenching cycles, new Tocco induction heating machine has copper heating and quenching coils and main housing of welded steel

...bi... design, new ...ube fur...ctured by Lindberg ...Co. em...rometer connected to ...rmocoup...emperature indication

...hi... Behind ...he Guns

...new ma..., see page 278)



Left—Combining a reversible air motor, a pneumatic type rivet squeezer and a unique four-way valve control, the Thor automatic rivet driver has aluminum housing, ball bearing studs of NE 8630 steel, mandrel of SAE 4870 steel and valve sleeve of stainless steel

Right — Cross and corner-braced structural steel framework of welded construction makes Electric Manufacturing Company's new synchronous motor control rugged, insuring permanence to alignment of doors and control parts. Resynchronization and excitation at correct motor speed and rotor angle are effected through use of polarized field-frequency relay

...squ...its made of SAE ...ving ... been effected in ...ll m...e through ingeni... ...and ...nal driving gears

Design Roundup

Low Alloy Has High Strength

A NEW HIGH-STRENGTH low alloy steel will shortly make its debut. Aimed particularly at the transportation field, this new moly-base steel will probably be made available on a license basis to steel companies. Developed by one of the country's outstanding metallurgists who already has to his credit several outstanding low-alloy steels, the new product will provide higher strength, lighter weight and easier fabrication, it is claimed.

Storage Battery for Welding

REVOLUTIONARY development in equipment for resistance welding of aluminum may be announced in the near future, using storage battery power, no condenser banks and a new type of carbon-pile contactor held closed under 25-ton pressure. It should prove highly important in a wide variety of aircraft welding work, thus stimulating the redesign of rivet assemblies to welding.

Subzero Treatment for Precision

DIMENSIONAL stability of steel has become a matter of increasing importance during the war because so much equipment requires extreme precision. Outstanding examples are gage blocks, instruments and machine elements. The two factors controlling dimensional stability of heat-treated steel during subsequent service are the release of internal stresses created by heat treatment and the change from one metallurgical phase to another. Annealing is the accepted procedure for eliminating locked-up stresses, but only recently has a means been found for preventing phase changes. It is well known that all of the austenite is not transformed into martensite after heating and quenching during the conventional hardening cycle, and it is this untransformed portion that causes dimensional changes over a period of time. The new procedure is to process the steel in a refrigeration unit at temperatures as low as minus 120 degrees Fahr. and allow it to reach room temperature, during which cycle the large part of the remaining austenite is transformed to martensite. Repeated cycles of chilling and drawing will eventually give a 100 per cent transformation and therefore complete stabilization. A concomitant advantage accruing from the refrigeration cycle is an additional hardness developed in the steel.

Deserves Consideration

CENTRIFUGAL CASTING methods have developed to a point where the designer must consider its possibilities from a cost standpoint. Apparently there are few jobs too tough for this new fabricating method. Ship shafting, for example, is now being cast centrifugally with reportedly high physicals. Also thin tubing with numerous fins for heat dissipation is successfully produced by this method. Tolerances as close as .0005-inch can be maintained in some cases, and the process is applicable to any metal, including alloy steels as well as nonferrous metals.

Depends on High-Temperature Alloys

JET-PROPULSION MOTOR development, which made possible the new planes now capturing the imagination of the general public, was in part due to high-temperature alloys. The principle involved in jet propulsion is not new, yet the problems involved in designing such a motor were almost insurmountable because no materials were available which would withstand the stress of continual operation at temperatures of 1500 degrees Fahr. and higher. These same alloys have done yeoman service in other applications, such as the turbosupercharger which makes possible high altitude flying, and in the new gas turbines which have immense possibilities in all fields of motive power.

Synthetic Problems

LAUNDRY MACHINE manufacturers are considerably worried about postwar problems. The new synthetics will be difficult to process through washing, dry cleaning and ironing. They won't stand many of the solutions now used. Heat and pressure cause some to shrink, melt or disintegrate, and others lose their strength during drying.

Formula Aids Calculation of Curve Length

By M. W. Powell
Ogle Construction Co., Chicago

ACCURATE determination of curved lengths such as tubing, conduit, airplane wing contours, structural sections, etc., can be effected quickly through use of the approximate formula presented in this data sheet. The only measurements required are the chord length and the angle between the tangent lines at the two ends of the curve. When applied to a range of circular arcs up to 90 degrees subtended angle the maximum error is less than .03 per cent

ANY CURVE in which curvature changes are not too abrupt may be assumed equal in length to a circular arc having the same chord and the same angle between tangents (or normals) at the two ends of the curve. Referring to *Fig.* 1, the curve length is A, the chord is C and the angle is 2α. If the curve is a circular arc, then the following exact relations apply:

$$A = 2R \text{ radian } \alpha \qquad (1)$$

$$C = 2R \sin \alpha \qquad (2)$$

where α is half the angle subtended by the arc and R is the radius. Elimination of the radius leads to the following equation for the ratio of arc to chord:

$$\frac{A}{C} = \frac{\text{radian } \alpha}{\sin \alpha} \qquad (3)$$

Although this is an exact equation, the inconvenience of converting the angle α to radians and also looking up the value of $\sin \alpha$ makes it highly desirable to derive from it a new expression in which the angle appears directly, as measured in degrees. This was done by expanding the functions of α in the form of an infinite series and converting radians to degrees. When the resulting series was studied, it was observed that a close working approximation was obtained by dropping all but the first three terms and modifying the constants. As finally derived, the approximate expression is

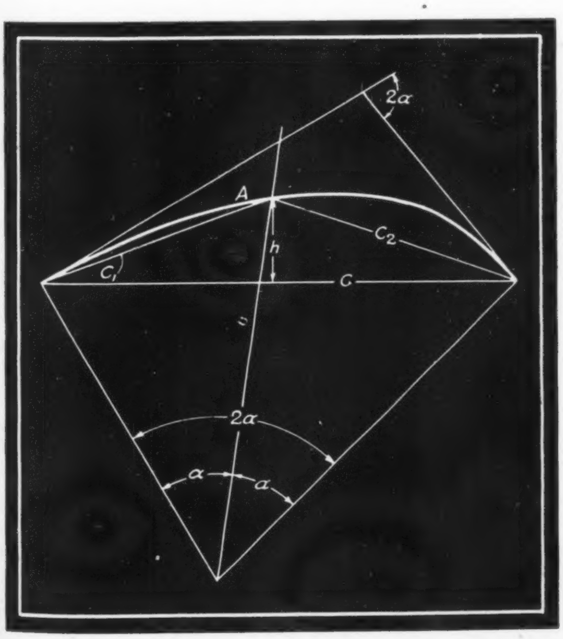


Fig. 1—Formula is based on the assumption that curve length is equal to the length of a circular arc having the same chord and subtended angle

$$\frac{A}{C} \approx 1 + \frac{\alpha^2}{20{,}000} + \left(\frac{\alpha^2}{20{,}000}\right)^2 \qquad (4)$$

$$\approx 1 + P + P^2 \qquad (5)$$

or

$$A \approx C + CP + CP^2 \qquad (6)$$

where α is in degrees and $P = \alpha^2/20{,}000$, which may be simply expressed as $\alpha^2/200$ per cent and is easily handled by a slide rule.

In order to test the accuracy of the equation, calculated values were compared with exact values which can be found from Equation 3 or, more conveniently, from published tables*. The comparison is shown in TABLE I. Although it would be neither practical nor desirable to apply the formula to curves which approach $2\alpha = 180$ degrees, the accuracy even in such extreme cases is within the limits usually required in engineering work.

Measurement of the angle 2α with a protractor to the nearest half degree, corresponding to quarter-degree accuracy for α, is sufficiently exact for most purposes. This

*Smoley—"Segmental Functions", 1941 edition, Page 251.

is because the terms involving the angle are a small percentage of the total chord or arc length and are added to the chord. The angle may be measured at the intersection either of the two tangents or of the two normals. Also, it will be observed that no measurements of radius of curvature are necessary. By choosing an intermediate point on the curve, using the two chords C_1 and C_2 and their subtended angles, a closer approximation is obtained.

EXAMPLE 1: Referring to *Fig.* 1, if the arc A is part of a curve having chord $C=12$ inches and subtended angle $2\alpha=66$ degrees, then $\alpha=33$ degrees and $P=33^2/20{,}000=.05445$. Substituting in Equation 5:

$$\begin{aligned} A &= 12\ (1+.05445+.05445^2) \\ &= 12\times 1.05741 \\ &= 12.6889 \text{ inches} \end{aligned}$$

EXAMPLE 2: Length of the curve shown in *Fig.* 2 may be determined with any required degree of accuracy,

TABLE I

Comparison of Exact and Approximate Formulas

2α	α	P	A/C (exact)	A/C (approx.)	Error
20°	10°	.005	1.0050949	1.0050250	—.0000699
40°	20°	.02	1.0206000	1.0204000	—.0002000
60°	30°	.045	1.0471976	1.0470250	—.0001726
70°	35°	.06125	1.0650110	1.0650016	—.0000094
80°	40°	.08	1.0861000	1.0864000	+.0003000
100°	50°	.125	1.1391827	1.1406250	+.0014423
120°	60°	.18	1.2091997	1.2124000	+.0032003
140°	70°	.245	1.3001383	1.3050250	+.0048867
160°	80°	.32	1.4178026	1.4224000	+.0045974
176°	88°	.3872	1.5368255	1.5370464	+.0002209
180°	90°	.405	1.5707963	1.5690250	—.0017713

depending on how many intermediate points are chosen.

As a first approximation, the curve is assumed equal to an arc corresponding to the chord A, the length of which is 189.74 inches. The angle between the normals is 80 degrees, hence $\alpha=40$ degrees and $P=40^2/20{,}000=.08$. Substituting in Equation 6:

$$\begin{aligned} \text{Arc length} &= 189.74+189.74\times .08+189.74\times .08^2 \\ &= 189.74+15.19+1.218 \\ &= 206.148 \text{ inches} \end{aligned}$$

Dividing the curve into two portions corresponding to the chords B_1 and B_2, it is found that $B_1=139.94$ inches and $B_2=61.19$ inches. The respective angles between the normals are 36 and 44 degrees ($\alpha=18$ and 22 degrees, $P=.0162$ and $.0242$). Then

$$\begin{aligned} B_1\ (\text{arc}) &= 139.94+139.94\times .0162+139.94\times .0162^2 \\ &= 139.94+2.265+.0366 \\ &= 142.2416 \text{ inches} \\ B_2\ (\text{arc}) &= 61.19+61.19\times .0242+61.19\times .0242^2 \\ &= 61.19+1.481+.0359 \\ &= 62.7069 \text{ inches} \\ \text{Total curve length} &= 142.2416+62.7069 \\ &= 204.9485 \text{ inches} \end{aligned}$$

Further subdivision, as shown in *Fig.* 2, results in the following values for arc lengths:

$$\begin{aligned} C_1\ (\text{arc}) &= 77.4067 \text{ inches} \\ C_2\ (\text{arc}) &= 64.8876 \text{ inches} \\ C_3\ (\text{arc}) &= 30.0885 \text{ inches} \\ C_4\ (\text{arc}) &= 32.4650 \text{ inches} \end{aligned}$$

$$\text{Curve length} = 204.8478 \text{ inches}$$

Alternatively,

$$\begin{aligned} C_1\ (\text{arc}) &= 77.4067 \text{ inches} \\ D\ (\text{arc}) &= 94.8265 \text{ inches} \\ C_4\ (\text{arc}) &= 32.4650 \text{ inches} \end{aligned}$$

$$\text{Curve length} = 204.6982 \text{ inches}$$

Comparison of these values indicates that with curves of the nature shown in *Fig.* 2 it is unnecessary to subdivide the length into a large number of parts.

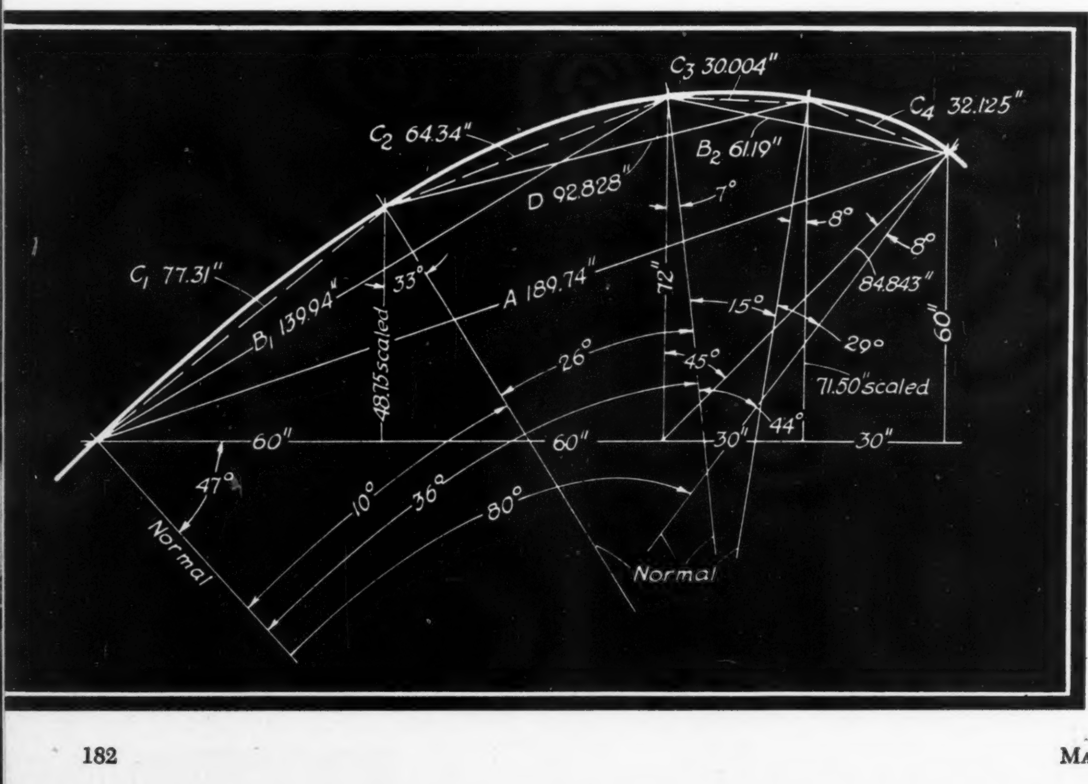


Fig. 2—Any desired degree of accuracy can be obtained by subdividing the curve and adding the calculated lengths of each section

Materials Work Sheet

Filing Number 12.00

Phosphor Bronzes

ASTM No. B103-43, grades A, B, C, D
B139-42T, grades A, B1, B2, C, D
B159-43T, grades A, C, D

AVAILABLE IN:

B103-43, grades A, B, C, D .... Sheet and strip
B139-42T, grades A, B1, B2, C, D ..... Rods, bars and shapes
B159-43T, grades A, C, D .... Wire

ANALYSES:

	Grade A	Grade B	Grade B1	Grade B2	Grade C	Grade D
Copper plus following elements (min.)	99.5	99.5	99.5	99.5	99.5	99.6
Tin	3.5 to 5.8	4 to 5.5	3.5 to 5.8	3.5 to 4.5	7 to 9	9 to 11
Phosphorous	.03 to .35	.03 to .25	.03 to .35	.03 to .5	.03 to .35	.03 to .25
Iron (max.)	.1	.1	.1	.1	.1	.1
Lead	.05 max.	2.5 to 4	.8 to 1.25	3.5 to 4.5	.05 max.	.05 max.
Antimony	.01 max.	....	....	....	.01 max.	.01 max.
Zinc	.3 max.	.2 max.	.3 max.	3 to 4.5	.2 max.	.2 max.
Copper	remainder	remainder	remainder	remainder	remainder	remainder

In the case of Grade A rods 1.25 inch and over in diameter, a manganese content of .5 maximum per cent may be permitted and the maximum iron content may be increased to 1 per cent.

PROPERTIES

TENSILE STRENGTH
(1000 *psi*)

RODS AND BARS, MINIMUM VALUES*

	Grades A	B	B1	B2	C	D
Rounds and hexagons, as drawn						
.250 to .500-in.	70	..	60	60	85	95
.501 to 1.000-in.	60	..	55	55	75	85
1.001-in. and over	55	..	50	50	60	70
Squares and rectangles, as drawn						
.250 to .375-in.	60	..	55	55	68	76
.376-in. and over	55	..	50	50	60	70

SHEET AND STRIP*

	A	B	B1	B2	C	D
Soft temper (minimum)	40	40	..	..	53	58
(maximum)	55	55	..	..	67	73
Half-hard temper (minimum)	55	55	..	..	69	76
(maximum)	70	70	..	..	84	91
Hard temper (minimum)	72	72	..	..	85	94
(maximum)	87	87	..	..	100	109
Extra-hard temper (minimum)	84	84	..	..	97	107
(maximum)	99	99	..	..	112	122
Spring temper (minimum)	91	91	..	..	105	115
(maximum	105	105	..	..	119	129
Extra-spring temper (minimum)	96	96	..	..	110	120
(maximum)	109	109	..	..	122	133

GENERAL PURPOSE WIRE*

	A	B	B1	B2	C	D
Soft temper (minimum)	43	..	..	..	53	60
(maximum)	58	..	..	..	68	75

*Values conform to ASTM specifications.

MACHINE DESIGN is pleased to acknowledge the collaboration of the following companies in this presentation: The American Brass Co.; The Phosphor Bronze Smelting Co.; The Riverside Metal Co.; Scovill Manufacturing Co.

TENSILE STRENGTH (*cont'd*)

	A	B	B1	B2	C	D
Quarter-hard temper (minimum)	60	..	..	..	74	83
(maximum)	76	..	..	..	91	102
Half-hard temper (minimum)	80	..	..	..	95	108
(maximum)	97	..	..	..	115	129
Three-quarter hard (minimum)	96	..	..	..	113	125
(maximum)	115	..	..	..	135	148
Hard temper (minimum)	108	..	..	..	125	135
(maximum)	128	..	..	..	150	160

SPRING WIRE, MINIMUM VALUES*	Grade A only
.025-in. and under diam.	150
Over .025 to .0625-in. diam.	135
Over .0625 to .125-in. diam.	130
Over .125 to .250-in. diam.	125
Over .250 to .375-in. diam.	120
Over .375 to .500-in. diam.	105

Note: When wire is ordered in straight lengths, the required minimum tensile strength is 15 per cent less than that listed above.

ELONGATION
(*per cent in 2 inches*)

MINIMUM VALUES*

	Grades A	B1	B2	C	D
Rounds and hexagons, as drawn					
.250 to .500-in.	12	12	12	12	12
.501 to 1.000-in.	15	15	15	15	15
1.001-in. and over	20	20	20	20	20
Squares and rectangles, as drawn					
.250 to .375-in.	10	10	10	10	10
.376-in. and over	15	15	15	15	15

Materials Work Sheet

ELONGATION (*cont'd.*)

Spring wire					
Over .025 to .0625-in. diam.	1.5	..	..	..	..
Over .0625 to .125-in. diam.	2.0	..	..	..	..
Over .125 to .250-in. diam.	3.5	..	..	..	..
Over .250 to .375-in. diam.	5.0	..	..	..	..
Over .375 to .500-in. diam.	9.0	..	..	..	..

ROCKWELL B-SCALE HARDNESS

SHEET AND STRIP°	Grades A Min.	A Max.	B Min.	B Max.	C Min.	C Max.	D Min.	D Max.
Soft temper								
.02 to .04-in. thk.	0	45	0	45	20	66	25	71
.04-in. and over	7	50	7	50	29	70	35	75
Half-hard temper								
.02 to .04-in. thk.	53	78	53	78	69	88	74	93
.04-in. and over	60	81	60	81	76	91	78	95
Hard temper								
.02 to .04-in. thk.	80	88	80	88	89	95	92	100
.04-in. and over	82	90	82	90	91	97	94	101
Extra-hard temper								
.02 to .04-in. thk.	86	92	86	92	93	98	97	102
.04-in. and over	88	94	88	94	95	100	98	103
Spring temper								
.02 to .04-in. thk.	88	94	88	94	95	100	98	103
.04-in. and over	90	96	90	96	97	102	99	104
Extra-spring temper								
.02 to .04-in. thk.	89	94	89	94	96	101	99	104
.04-in. and over	92	97	92	97	98	103	100	105

BEND RADII FOR RODS AND BARS

Rounds, hexagons, squares, and rectangles of these materials can be bent cold through 120 degrees to a radius equal to the diameter or thickness, without fracturing.

APPLICATIONS

Grade A: (5% tin) Used extensively for springs, diaphragms, bellows, lock washers, cotter pins, fuse clips, clutch disks, screw-machine stock, bushings, wire rope, textile ring travelers, welding rods and pump rods.

Grade B1: Small gears, pinions, screws, bearings, and other similar screw-machine products which must be highly resistant to wear and corrosion.

Grade B2: Is a free-cutting alloy, its machinability matching that of yellow brass. It is particularly suitable for small bearings, bushings, valve and pump parts, gears and pinions and other parts which require high resistance to wear.

Grade C: Used for springs on electrical apparatus, diaphragms, welding rod and springs of all kinds where greater elasticity, strength and endurance are required than in the case of springs made of Grade A phosphor bronze.

Grade D: Applications requiring the greatest hardness, strength and wear resistance of any of the wrought phosphor-bronze alloys. Typical applications are diaphragms, springs, paper-mill machinery parts such as jordan and beater bars, rock drill rifle nuts, locomotive bearing-plate liners, fog-horn and whistle diaphragms, and other similar springs and parts requiring the utmost in strength and resistance to wear.

CHARACTERISTICS

Outstanding characteristics of phosphor bronzes are their extraordinary strength and toughness, their high resistance to corrosion, fatigue and corrosion-fatigue, their low coefficient of friction with most other metals and alloys, and their high immunity to season cracking. They are used extensively for springs requiring high resistance to repeated stresses as well as resistance to corrosion and corrosion simultaneously with fatigue. Also, they are used extensively for bearings and wearing parts and for current-carrying springs in electrical circuits where arcing can occur.

FABRICATION

MACHINABILITY:

General good practice prescribes the use of highest practical cutting speed, a relatively light feed and a moderate depth of cut. Approximate relative machinability ratings listed below are based on a value of 100 for free-cutting yellow brass.

Machinability Ratings

Grade A—20 Grade B1—50 Grade B2—100
Grade C—20 Grade D—20

To permit long production runs at high cutting speeds, tungsten-carbide-tipped tools are used. However, for short or moderate runs, high-speed steel tools prove adequate. Soluble oils are used as a lubricant on the soft alloys. However, the more refractory phosphor bronzes require a lubricant as well as a coolant.

OTHER PROPERTIES
(applying to all forms)

	Grades A	B1	B2	C	D
Yield Strength at .5% elongation under load. (For 1-in. diam. bar.) Commercial hard temper, average (psi)	55,000	55,000	45,000	....	....
Soft annealed, average (psi)	20,000	....	....	24,000	....
Melting Point, deg. Cent.	1050	1050	1000	1025	1000
deg. Fahr.	1922	1922	1832	1877	1832
Weight (lb. per cu. in.)	.3205	.322	.32	.3184	.317
Specific Gravity	8.88	8.91	8.86	8.82	8.77
Coef. of Linear Thermal Expansion (per deg. F., 77-572 deg. F.) average	.0000106	.0000099	....	.0000101	.0000102
Electrical Conductivity, volumetric (% of Int'l. Ann'ld. Copper Std.) At 20 deg. Cent.	14	18.4	12.2	13	11
Thermal Conductivity (g-cal/sq cm/sec/deg. C/cm) At 20 deg. Cent.	.18	.2	.133	.15	.12
Modulus of Elasticity (psi)	ranges from 14,500,000 to 15,500,000				

DRILLING:

For drilling grades B1 and B2 it is often found advisable to grind the rake angle of a standard twist drill to zero degrees and flatten the cutting edge angle approximately 6 to 8% of the drill diameter. Standard twist drills are satisfactorily used without alteration on grades A, C and D, although the so-called high-spiral drills having a helix angle of about 40 degrees are particularly suitable, especially for deep drilling. Although these materials are often drilled dry, lubrication is recommended, especially for grades A, C and D.

REAMING:

When specifying the size of drilled hole to precede reaming, leave sufficient stock in the hole, especially where wall thickness is small in relation to the hole diameter. Such precaution will insure against burnishing action which results in undersize holes and excessively rapid wear of the reamer. Straight-fluted reamers have a tendency to chatter on some types of work. Standard spiral-fluted reamers with 7 to 12-degree helix angle work satisfactorily, while the left-hand spiral, right-hand cutting types give excellent results.

TAPPING:

Except in the comparatively few cases where an extremely close thread fit is required, it is advisable to specify a tap-drill size which will result in a 75% depth of thread. 100% threads are only 5% stronger than 75% threads, but require more than twice the power to tap and, in addition, present problems of chip ejection and correct tap design for the particular metal. An ample supply of cutting fluid is used on all tapping operations.

STAMPING, FORMING AND DRAWING:

For punching and blanking phosphor bronze sheet and strip, it is recommended that the same tools and tool clearances be used as are used for cold-rolled steel of similar thickness. In the annealed condition, the phosphor bronzes have a higher hardness for a given annealed temper than cartridge metal (70-30 Cu/Zn). Consequently, the tensile strength for a given per cent reduction would be higher for similar reductions compared to cartridge metal. Due to the higher hardness of the bronzes, more power, lower speed and stronger tools are necessary for drawing compared to deep-drawing brasses. Generally speaking, these bronzes have good deep-drawing qualities. Maximum radius in the dies for cup drawing should be about 10 times the metal thickness to avoid wrinkling. In deep drawing, lubrication is of the utmost importance in order to keep the formation of abrasive tin compounds on the metal surface at a minimum. Such oxides load up drawing tools and result in galling the work. For bending work, the following is offered only as a general guide: Flat springs, formed with easy bends across the grain, are usually made of Grade A in spring temper. Flat springs with easy bends across and with grain are usually made of Grade C in extra hard temper. Clips or contact springs with most difficult bends are generally made of Grade C in hard temper.

WELDING:

Grades A and C are used extensively for arc welding where the carbon-arc or metal-arc methods are employed. Practically any metal having a higher melting point than the phosphor bronzes can be welded with them. Good welds can be made on wrought, malleable and cast iron, low and high-carbon steel, galvanized iron, bronzes, brasses and copper. When welding steel or iron, the parts to be welded are left cold, but when welding copper or alloys of copper, best results are obtained when the parts are preheated at the starting point. In metal-arc welding, the phosphor-bronze rod is positive and a greater current should be used than with steel rod of the same size.

Phosphor bronzes are rated as "poor" for oxyacetylene welding. In carbon-arc welding Grade D rates "good"; B-1 is "fair"; and B and B2 are "poor". In resistance, spot and seam welding, Grades A, C and D are "fair to good" and B1 is "fair". In this method, however, there is a tendency for the metal to stick to the electrodes. Grades B and B2 are rated "poor" for resistance welding.

A special phosphor bronze alloy having low tin and phosphorus contents (composition about 1.7% tin, .03% phosphorus, remainder copper) is used for acetylene-gas welding.

BRAZING:

All of the phosphor-bronze alloys are readily brazed either in a furnace, using a torch, dipping the parts into a molten alloy bath, or by electrical resistance. There are a variety of satisfactory brazing alloys, including copper-zinc alloys, copper-nickel-zinc alloys and silver brazing alloys. They require the use of borax or boracic-acid flux. Combinations of borax and sodium fluoride are also used for brazing fluxes. All fitted joints should be properly cleaned prior to heating. Brass and nickel-silver alloys may be obtained with a melting point of about 1650 degrees Fahr. and silver alloys are procurable with a variety of melting temperatures.

SOLDERING:

All of the phosphor-bronze alloys can be soldered satisfactorily. Surfaces to be soldered are carefully cleaned either by mechanical or chemical means and the metal surfaces are brought up to a temperature equivalent to that at which the solder will flow. There are many commercial soldering compounds on the market, or ordinary rosin may be used when it is impossible to remove corrosive fluxes by washing.

RESISTANCE TO CORROSION

These alloys have good resistance to rural, industrial and marine atmospheres and in fresh water their resistance is almost equally as good. They also offer good resistance to sea water. In contact with foods, they should be tin coated, not so much for resistance to corrosion but to avoid contamination of the food.

Grades A, C and D phosphor bronze rate as follows in their resistance to corrosion (at temperature of 20 degrees Centigrade) when used with the agents named:

Hydrochloric Acid: Not recommended in moderate dilution or concentrated form. Approved in very dilute state subject to individual conditions about which producer should be consulted.

Sulphuric Acid, Acetic Acid, Sodium Hydroxide, Sea Water and **Brines, Calcium** and **Magnesium Brines:** Approved in very dilute, moderate dilute or concentrated form subject to individual conditions about which producer should be consulted.

Nitric Acid and **Ammonium Hydroxide:** Not recommended in very dilute, moderate dilute or concentrated form.

Phosphoric Acid, Chlorine in **Aqueous Solution, Mine Waters, Fatty Acids, Fruit** and **Vegetable Juices, Dye Liquors, Moist Sulfurous Atmosphere:** Approved subject to individual conditions about which producer should be consulted.

Sea Air: Approved.

Materials Work Sheet

GALVANIC CORROSION

These alloys are more noble than most of the common metals and alloys. Coupling of them with metals such as steel, zinc, aluminum, stainless steel and lead in the presence of a liquid having good conductivity, will result in attack of the latter metals and protection of the phosphor bronze. Coupling of phosphor bronze with nickel and high-nickel alloys under similar conditions may result in a slightly accelerated attack on the phosphor bronze. Galvanic corrosion of the less noble metal may, in any case, be slight or severe, depending on a number of factors, such as relative areas of the two metals in contact, electrical resistance of the circuit, polarization effects, etc.

DATA ON STOCK FORMS

Rod and Bar
STANDARD TOLERANCES*

Diam. or Distance Across Flats	Tolerance—Plus or Minus (inches) Rounds	Squares, Hexagons, Octagons
.25 to .5-in.	.002	.004
Over .5 to 1-in.	.003	.005
Over 1 to 2.5 in.	.004	.006
Over 2.5 in.	.2 per cent†	.4 per cent†

†Expressed to the nearest .001-inch.

Sheet and Strip
Slit and Slit-rolled Edges
STANDARD WIDTH TOLERANCES*

Width (inches)	Tolerance§ Plus or Minus .004 to .032 inch Thick	Over .032 to .182-in. Thick
2 and under	.005	.010
Over 2 to 8 incl.	.008	.013
Over 8 to 14 incl.	.010	.015
Over 14 to 20 incl.	.013	.018

Sheet and Strip
Square Sheared Metal
(all lengths up to 120 in. incl.)
STANDARD WIDTH TOLERANCES*

Width (inches)	Tolerance§ Plus or Minus 1/16-in. and under Thick	Over 1/16 to 1/8 in. Thick	Over 1/8-in. Thick
20 and under	1/32	3/64	1/16
Over 20 to 36 incl.	3/64	3/64	1/16
Over 36 to 60 incl.	1/16	1/16	1/16

§ When tolerances are specified as all plus or all minus, double the above values.

Wire
DIAMETER TOLERANCES*

Diam. (inches)	Tolerance Plus or Minus (inches)
.02 to .03	.0005
Over .03 to .04	.0007
Over .04 to .05	.0008
Over .05 to .06	.001
Over .06 to .08	.0015
Over .08 to .5	.002

Weights of Bars and Plates

Diam. or Thickness (inches)	Weight of Bars 1 foot long— Rounds (lbs)	Squares (lbs)	Hexagons (lbs)	Weight of Plates 1 foot square (lbs)
1/16	.012	.015	....	2.9
1/8	.047	.06	.052	5.8
3/16	.106	.135	.118	8.7
1/4	.188	.24	.21	11.6
5/16	.294	.375	.328	14.5
3/8	.424	.54	.472	17.2
7/16	.557	.736	.643	20
1/2	.755	.96	.839	22.9
9/16	.955	1.215	1.06	25.7
5/8	1.17	1.5	1.31	28.6
11/16	1.42	1.81	1.58	31.4
3/4	1.69	2.16	1.88	34.3
13/16	1.99	2.53	2.21	37.2
7/8	2.31	2.94	2.57	40
15/16	2.65	3.37	2.94	42.9
1	3.02	3.84	3.35	45.8
1 1/8	3.82	4.86	4.25	51.6
1 1/4	4.71	6	5.25	57.3
1 3/8	5.71	7.27	6.35	63
1 1/2	6.79	8.65	7.56	68.8
1 5/8	7.94	10.15	8.86	74.5
1 3/4	9.21	11.77	10.29	80.2
1 7/8	10.61	13.52	11.8	86
2	12.08	15.38	13.42	91.7
2 1/8	13.64	17.36	15.16	...
2 1/4	15.29	19.47	17	...
2 3/8	17.03	....	18.8	...
2 1/2	18.87	....	....	...
2 5/8	20.81	....	....	...
2 3/4	22.84	....	....	...
2 7/8	24.92	....	....	...
3	27.18	....	....	...
3 1/4	31.9	....	....	...
3 1/2	37	....	....	...
3 3/4	42.5	....	....	...
4	48.3	....	....	...
4 1/4	54.5	....	....	...
4 1/2	61.2	....	....	...
4 3/4	68	....	....	...

MATERIAL DESIGNATIONS

ASTM	AMS	SAE	Federal
	SHEET AND STRIP		
B103-43, Gr A	4510A	77, Gr A	QQ-B-746, Gr A
B103-43, Gr B	....	....	....
B103-43 Gr C	....	77, Gr C	....
B103-43, Gr D	....	....	QQ-B-746, Gr B
	ROD AND BAR		
B139-42T, Gr A	4625B	....	QQ-B-746, Gr A
B139-42T, Gr B1	....	....	....
B139-42T, Gr B2	....	....	....
B139-42T, Gr C	....	....	....
B139-42T, Gr D	....	....	....
	WIRE		
B159-43T, Gr A	4720A	81	QQ-W-401
B159-43T, Gr C	....	....	....
B159-43T, Gr D	....	....	....

Sheet and Strip
STANDARD THICKNESS TOLERANCES*

Thickness (inches)	Tolerance—Plus or Minus‡ (inches) 8 in. and under in width	Over 8 to 14 in. wide	Over 14 to 20 in. wide	Over 20 to 28 in. wide	Over 28 to 36 in. wide	Over 36 to 48 in. wide	Over 48 to 60 in. wide
.004 and under	.0004	.0008	....	...	...	...	...
Over .004 to .006 incl.	.0006	.001	.0015	...	...	...	...
Over .006 to .009 incl.	.0008	.0013	.002	...	...	...	...
Over .009 to .013 incl.	.001	.0015	.0025	...	...	...	...
Over .013 to .017 incl.	.0013	.002	.0025	...	...	...	...
Over .017 to .021 incl.	.0015	.0025	.003	...	...	...	...
Over .021 to .026 incl.	.002	.0025	.003	.004	.005	.006	.007
Over .026 to .037 incl.	.0025	.003	.0035	.005	.006	.007	.008
Over .037 to .050 incl.	.003	.0035	.004	.006	.007	.008	.010
Over .050 to .073 incl.	.0035	.004	.0045	.007	.008	.010	.012
Over .073 to .130 incl.	.004	.0045	.005	.008	.010	.012	.014
Over .130 to .205 incl.	.0045	.005	.006	.010	.012	.014	.016
Over .205 to .300 incl.	.005	.006	.007	.012	.014	.016	.018
Over .300 to .500 incl.	.006	.007	.008	.015	.017	.019	.023
Over .500 to .750 incl.	.008	.010	.012	.019	.021	.024	.029
Over .750 to 1.00 incl.	....	.012	.015	.023	.026	.030	.037
Over 1.00 to 1.50 incl.	....	....	....	.028	.032	.037	.045
Over 1.50 to 2.00 incl.	....	....	....	.033	.038	.045	.055

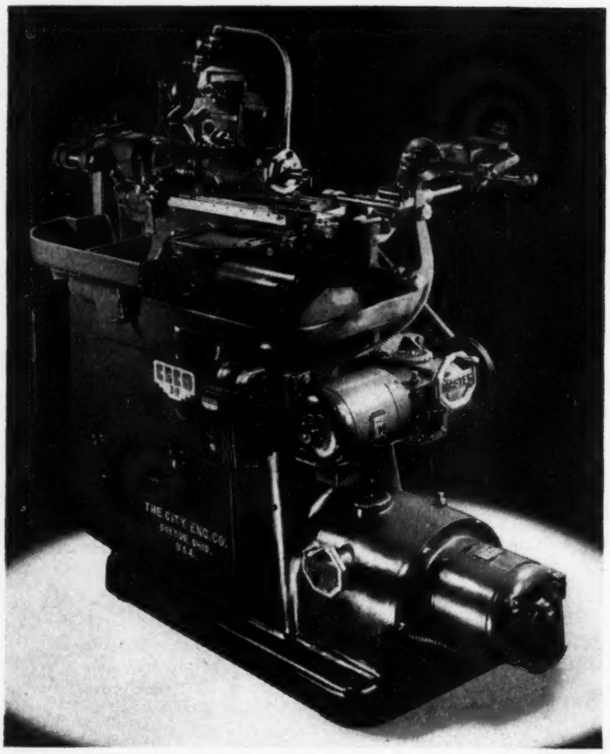
‡ When tolerances are specified as all plus or all minus, double the above values.

Note: For material .021-in. and under in thickness, it is recommended that the nominal thicknesses be stated not closer than the nearest half-thousandth. (For example, specify .006 or .0065, but not .0063).

For material over .021-in. thick, it is recommended that the nominal thicknesses be stated not closer than the nearest thousandth. (For example, specify .128 or .129, but not .1285).

Applications

of Engineering Parts, Materials and Processes

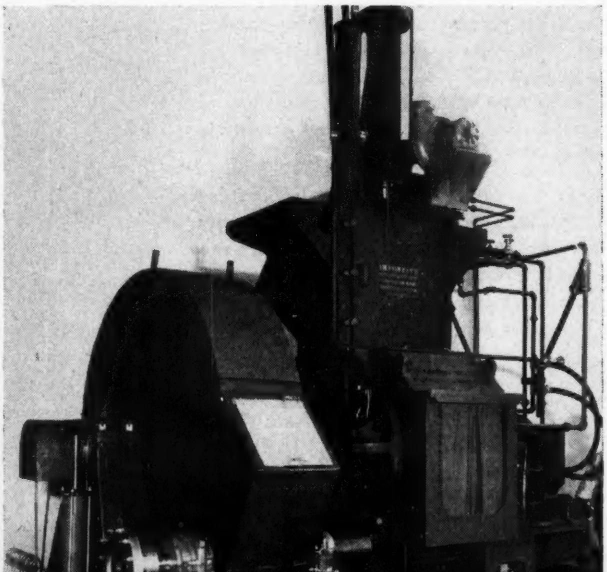


Uses Built-in Speed Changers

CORRECT speeds for the production of small intricate parts on the Ceco automatic shown at left are accurately and simply obtained through the use of Master Speed-Rangers. The large unit built into the machine base in the foreground drives the main spindle and provides stepless speed changes from 675 to 7500 revolutions per minute. The smaller unit located immediately above the larger operates the independent camshaft to give an infinitely variable range of cycle timing from three seconds to eight minutes.

Tubular Ring As Machine Frame

ROLLED from a single one-inch plate and arc welded longitudinally, the Dresser-built motor generator frame shown below is 17 inches outside diameter by 36¾ inches long. Fabricated as shown, the frame weighs 545 pounds. Feet and water-seal strips are arc welded and the openings are flame cut.



Lubricating a Rubber-Working Machine

WIDELY used in rubber processing, the Farrel-Birmingham-built Banbury mixer shown at left is equipped with a Trabon automatic lubricating system, employing the newly developed "type M" distributor. This is an assembly of three or more sections having different capacities so that lubricant is distributed to a cluster of nearby bearings in proportion to their needs. Grease from the reservoir is fed first to a master distributor which proportions part of the flow to the bearings on the near end of the machine. Remainder is passed through a single pipe to another distributor which meters lubricant to all bearings on the other end.

Master distributor is operated from a pump driven through an overrunning clutch from the shaft of the machine, the action being entirely automatic and continuous while the machine is in operation.

Professional Viewpoints

". . . powder metal as friction material"

To the Editor:

Colin Carmichael's article in the November issue on "Designing Powder Metal Machine Parts" is welcome because of its balanced treatment of this important subject. However, one field for powder metal parts might warrant further discussion.

Friction materials are used either dry, or "wet" by lubricant. In many applications it is desirable to install the friction clutch or brake in the same housing or lubricating system with other machine parts such as transmission gears and bearings. Since friction inevitably means wear, the designer at once asks what effect wear of the friction parts will have on other machine elements.

Proof that with proper materials and design no harm will be done is given by the thousands of airplane engines, tank transmissions, tractor drives, and marine transmissions now in use with powder metal clutch or brake elements operating in the same lubricant housing with gears and bearings of the highest finish and precision. As yet we have no evidence of clogging of oil lines or of damage to machine surfaces by particles worn from the powder metal friction surfaces. Reasons for this include:

1. Correct analysis of the application and provision of a suitable material or mix
2. The low rate of wear obtaining under the correct application
3. The nature and size of the particles worn from the friction faces.

Noteworthy new developments in mechanical transmissions are being built around sintered powder metal materials. This is a subject well worth study by the designer of machines.

—W. C. Sutton, *Chief Engineer*
The S. K. Wellman Co.

". . . numbers would not exceed 99,999"

To the Editor:

In your November issue the article "Does Your Numbering System Need Revamping?" was read with considerable interest. We revamped our numbering system a few years ago using designations of letters and numbers—the letters indicating first, product; second, drawing size; then a series of numbers of simple numerical value followed by another letter to indicate design grouping and, in some cases, by still a further letter such as —A or —B indicating design modifications. We, also, planned our system so that the numbers would not exceed 99,999 for at least thirty years, gaged by the rate of usage at that time, and if it had been necessary to maintain this limit

"I want A FLEXIBLE GASKET TO WITHSTAND 2000° F." said the airplane part maker

"I want A RUSTLESS, DURABLE PRESSING PAD" said the laundry operator

"I want A FINE TUBE GRID THAT WON'T SAG" said the electronic tube maker

"I want A LASTING WICK FOR AIRPLANE HEATERS" said the cabin heater maker

A true Cinderella, knit metal mesh started its working life in the kitchen.

It was made into pot cleaners . . . *super* cleaners, unusually tough and resilient.

Next, it jumped to the laundry. Knit Monel mesh gave . . . and is giving . . . years of extra life to steam pressing pads, used daily in commercial laundries.

Today, knit metal mesh, made by the Metal Textile Corp., Orange, N. J., does many diverse jobs in many different industries.

Tomorrow . . . ? Perhaps it's the answer to a problem now on *your* drafting board.

Knit metal mesh is made in a special *linked loop* design that assures flexibility, high resistance to breakage, and bias strength. The fabric holds together even when made of very fine wire (.0045 diameter), and with as few as 4 or 5 openings to the inch. It can be compressed lightly for air, liquid or gas filters . . . tightly for gaskets. It is made in a wide range of metals.

In applications requiring extra strength, toughness, corrosion resistance, and other specialized properties, INCO Nickel Alloys are used.

Thus, Inconel knit mesh is used for airplane exhaust stack gaskets that must retain resiliency at 1500° F. to 2000° F., and for capillary wicks in airplane cabin heating units.

Fine mesh is knitted from pure Nickel wire for electronic tubes. Monel mesh provides high-fatigue value and corrosion resistance in laundry pressing pads.

For further information write to the Metal Textile Corp., or to: The International Nickel Company, Inc., 67 Wall Street, New York 5, N. Y.

"I want A BETTER AIR FILTER MEDIUM" said the filter manufacturer

"I want A FLEXIBLE STRAP THAT WON'T JIGGLE LOOSE" said the magneto maker

INCO NICKEL ALLOYS

MONEL • "K" MONEL • "S" MONEL • "R" MONEL • "KR" MONEL • INCONEL • "Z" NICKEL • NICKEL • *Sheet . . . Strip . . . Rod . . . Tubing . . . Wire . . . Castings*

to the number of numerals used, we would have further subdivided our classifications to have made this possible because our experience has indicated that lengthy numbers are cumbersome to handle.

—F. L. Hemings, *Manager*
Production Engineering Dept.
American Engineering Co.

". . . of help in analyzing pump"

To the Editor:

The article in the November issue of Machine Design, "Auxiliary Points Aid Acceleration Analysis", by A. S. Hall and E. S. Ault was of considerable help to us in analyzing a variable stroke pump similar to the one shown in *Fig. 2* of the article. If available, we would appreciate receiving a reprint of this article for our files.

If you still have reprints of the earlier articles by the same authors on the subject "How Acceleration Analysis Can Be Improved", from your February and March issues, we would also appreciate having a copy of these articles.

—E. F. Wright, *Assistant to Chief Engineer*
Reciprocating Pump Engrg. Div.
Worthington Pump & Machinery Corp.

Reprints not being available, clip sheets of all three articles were gladly furnished to Mr. Wright.—Ed.

". . . an extra factor to consider"

To the Editor:

Will you please forward a copy of the article on "Does Your Numbering System Need Revamping?"

When I first read this article I was surprised at the similarity between the system mentioned and the one we had "cooked" up just recently. We had an extra factor to consider in our system and that was the date or model year because our products have design changes each year to agree with the product on which they are used. To accomplish this we used a numeral as the first digit in our number to show the model year. We followed this with one or two letters to designate the particular product and then numbers again to show variations of these products. So you can see there is quite a similarity between the two systems.

We also use a separate numbering system for standard parts, such as nuts, bolts, washers, etc., which enables us to do away with drawings on all these parts, effecting a considerable saving in time.

—F. C. Perry, *Chief Engineer*
Monarch Governor Co.

". . . for rapid calculations"

To the Editor:

May I comment on the article "Hydraulic Lines . . . What Material, What Size?" appearing in the December issue of Machine Design? Information of this nature is very helpful for rapid approximate calculations pertaining to its particular branch of hydraulics. The major

50 to 3000

Pounds Pressure from your Present Hydraulic Circuits with a

RACINE

Hydraulic Pressure BOOSTER

A high pressure, oil hydraulically actuated, compact, self-contained auxiliary to your present low pressure hydraulic circuit. Increases your source of force as much as 7 to 1. Creates new standards of flexibility and operating economy.

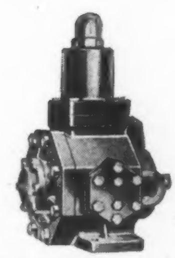
FOR NEW OR OLD HYDRAULIC CIRCUITS. Fits anywhere into your present or new hydraulic circuits without interference. Now you can obtain *high pressure when you need it—return to low pressure at will.* Use low horsepower motor and low pressure control valves—results in lower initial investment and reduced operating and maintenance costs.

Can be used in circuits with either variable or constant volume pumps.

Free from repairs — no gears to wear out — no driving mechanism to get out of adjustment. The Racine Hydraulic Pressure Booster is an exclusive patented unit. For complete information ask for illustrated bulletin. Address Dept. MD-P.

"Variable Volume" PUMPS
"Balanced-Piston" VALVES

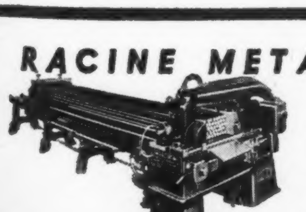
Include in your hydraulic circuits Racine Oil Hydraulic "Vane Type-Variable Volume" Pumps. Capacities 12 - 20 - 30 G.P.M. Operating pressures 50 to 1,000 pounds per square inch. Racine "Balanced-Piston" Valves insure ease of operation. Sizes ⅜" to 1½". Available with manual, solenoid, pilot and mechanically operated devices. Let Racine engineers help you with your oil hydraulic applications. Ask for Bulletin P-10-C.



Racine "Variable Volume" Oil Hydraulic Pump

RACINE
TOOL and MACHINE COMPANY
Standard for Quality and Precision
RACINE, WISCONSIN, U. S. A.

RACINE METAL CUTTING MACHINES



Racine Hydraulic Automatic Stock Feed Machine

For 36 years Racine has led the field in metal cutting machines. Positive screw feed and the application of hydraulic operation, feed and control to metal cutting machines of the reciprocating type, were first developed by Racine. A full line—capacities 6" x 6" to 20" x 20".

reason for this is, of course, that although pressure drop in conduits is as old as basic hydraulics, very little first-hand information is available in treatise form as given in your publication.

—J. F. MELICHAR, *Development Engineering*
The Parker Appliance Co.

". . . reporting engineering meetings"

To the Editor:

Some time ago there appeared in MACHINE DESIGN an editorial concerning engineering meetings which, no doubt, voices the feelings of many technical men. Not all men who want to attend such meetings can do so. Here is where an active technical press, of which your journal is an outstanding member, can and does meet the needs of these men by conscientiously reporting the papers presented at engineering meetings.

—C. E. SCHIRMER, *Chief Engineer*
Hoist and Crane Div.
Robbins & Myers Inc.

". . . difficulties in patent systems"

To the Editor:

I always read with great interest Mr. Woodling's articles, and believe that all engineers can learn a lot from such patent analysis. Commenting particularly on his article in your September issue with respect to the difficulties which are encountered in our present patent system—from the beginning of the filing of an application to the final adjudication thereof—experience shows that the main difficulty always arises from the fact that our system calls upon men of legal qualifications to decide on the merit or drawback of a technical question. Obviously the judge or attorney cannot penetrate to the substance of the invention, but is influenced by signs, revelations, witness stories, etc.

It is no less inhuman to demand from a jurist to pass on a "Bendix drive" than it would be for an engineer to pass on a legal case involving the question of declaratory judgment. For this reason the report of the National Planning Commission is not satisfactory in claiming that objective and not subjective tests should determine patentability. The man has to pass on objective results based on his subjective capacity and, therefore, a person dealing with patent matters should have, next to his legal qualifications, basic engineering training plus experience. This has been recognized a long time ago in several foreign countries and has eliminated lots of waste and repetition.

—E. K. BENEDEK

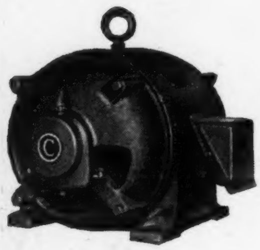
POWERFUL searchlight has been designed for operation on twenty-four volts. Because arcs are normally unstable at less than fifty-four volts, a new type of carbon electrode together with a new control scheme was developed for the application.

New PARTS AND MATERIALS

General Purpose and Splashproof Motor

BUILT with feet cast integral with the cast-iron frame which is ribbed to withstand strain, the new squirrel cage induction polyphase motors announced by Century Electric Co., 1806 Pine street, St. Louis 3, are available in sizes from 1½ to 15 horsepower.

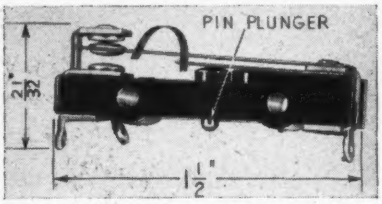
Form-J general-purpose, open-rated motor is built in a new protected design—the upper half of the end bracket being closed to minimize the possibility of dripping liquids or falling solids entering vital parts of the motor. Two powerful fans behind the bearing brackets draw cooling air through the bearing-bracket openings, around the bearings, across the windings and to the air passages between the outer surfaces of the magnetic core and the frame—the heated air being expelled through openings at the side and bottom of the frame.



The other Form-J motor is splashproof and is available in the same horsepower ratings, with two-way ventilation. Cooling air in this motor is drawn through baffled openings in the bottom of the end brackets by a fan on each end of the rotor, blown through and around into all parts of the motor. The air is then expelled through louvred openings in the side of the frame below the center line and at the bottom. No drop of liquid nor solid particles falling on the machine or coming towards it in a straight line at any angle not greater than 100 degrees from the vertical can enter the machine either directly or by striking and running along a surface. Insulation is highly resistant to moisture, mild acids and alkalies. They are designed for use in dairy, laundry, brewery and bottling equipment and in other general industrial equipment.

Midget Snap-Action Switch

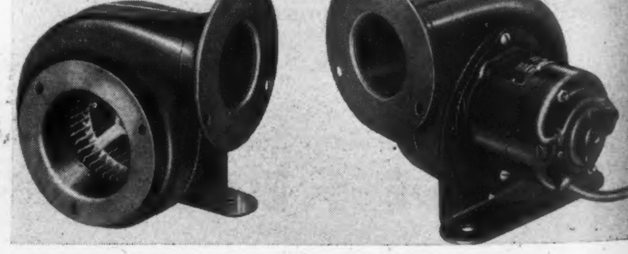
MANUFACTURED by Acro Electric Co., 1311 Superior avenue, Cleveland 14, a new midget switch, built on the rolling-spring principle, has maximum dimensions of 1½ inches. It is 9/16-inch wide, 7/16-inch thick, and weighs less than one ounce. Designed for actuation from either top or bottom, the switch is adapted to electronic control devices, machine tools, aircraft, and electrical appliances. All component parts are noncorrosive, the snapaction spring and center blade being beryllium

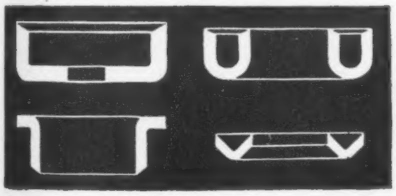


and the base, bakelite. According to the company, under factory tests the switch has shown no failure after 94 million operations, and it has stood the Winterization tests under Army Air Force Directive 21A, including salt spray tests and both high and low-temperature tests. When built into relays, smaller coils may be used as only 4 to 6 ounces operating pressure is required. The switch is furnished in single-pole, normally-open, normally-closed, and double-throw types with both pretravel and over-travel being provided.

Blower with Flexible Mounting

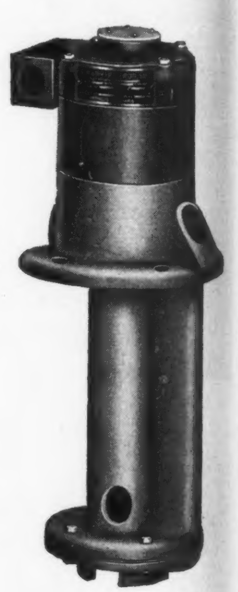
ESPECIALLY developed for machines with built-in air handling equipment, a new all-purpose blower unit announced by Ilg Electric Co., 2850 North Crawford avenue, Chicago 41, is available in eight different arrangements. These include blower only; blower and stand only; blower and inlet flange; blower and discharge flange; blower, inlet and discharge flange; blower, stand and inlet flange; blower, stand and discharge stand; or blower, stand, inlet and discharge flanges. Housing and stand of the No. 68 utility blower are die-stamped steel, and the dynamically balanced multiblade wheel is diecast zinc. Wheel and motor are direct-connected, result-





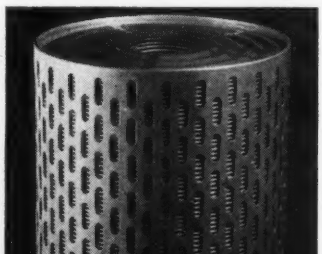
ing in a compact unit for inclusion in machines. It is powered by a series-wound, 110-volt, single-phase, 60-cycle, sleeve-bearing type alternating-current motor that operates 3400 revolutions per minute. A length of cord is brought out of the motor for making connections.

Adaptable Coolant Pump Offered



BECAUSE of its adaptability to various machines and its trouble-free operation, Model 7500 pump introduced by Brady-Penrod Inc., Muncie, Ind., has become one of the most popular in the company's line. Having three flange depths, making possible its use on any grinder, lathe, cutting or drilling machine, the pump has no seal, couplings, gears, belts or any other intricate parts. It has an open, wide-clearance impeller, integral one-piece shaft and motor rotor. Its motor is of totally enclosed, heavy-duty, oversize type. The pump incorporates a controlled flow, ranging from a drop per minute to full pump capacity, which is regulated by a valve in the discharge line. It can easily be adapted to any sump or tank through a short metal lid or cross-arm strips. Rating of the pump is from ⅛ to ½-horsepower.

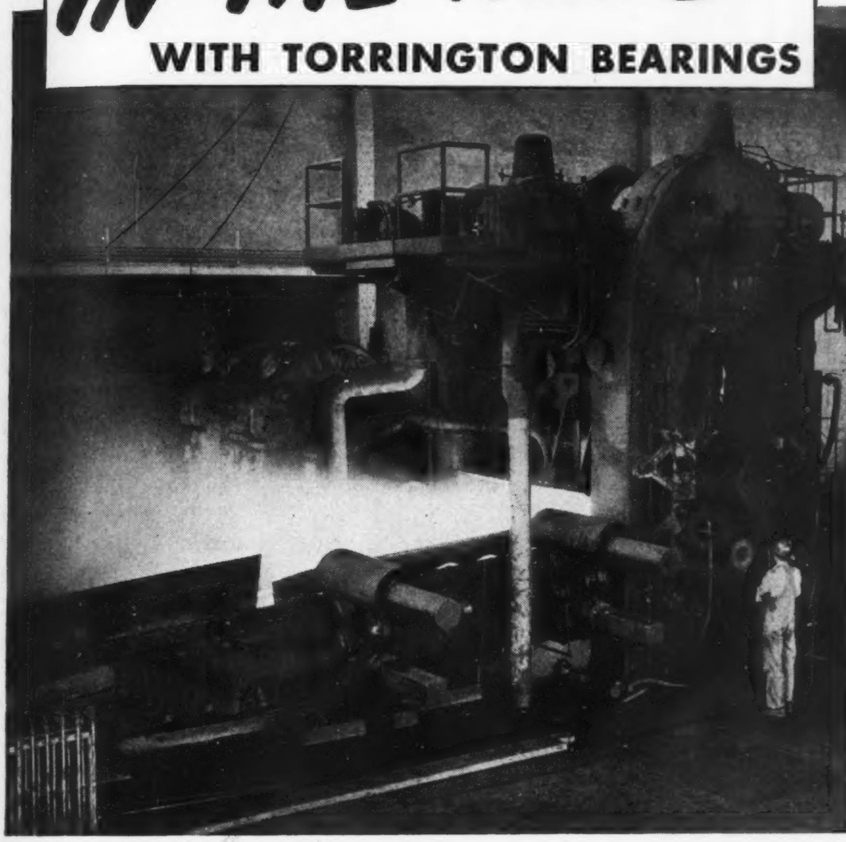
Hydraulic Filter for Aircraft



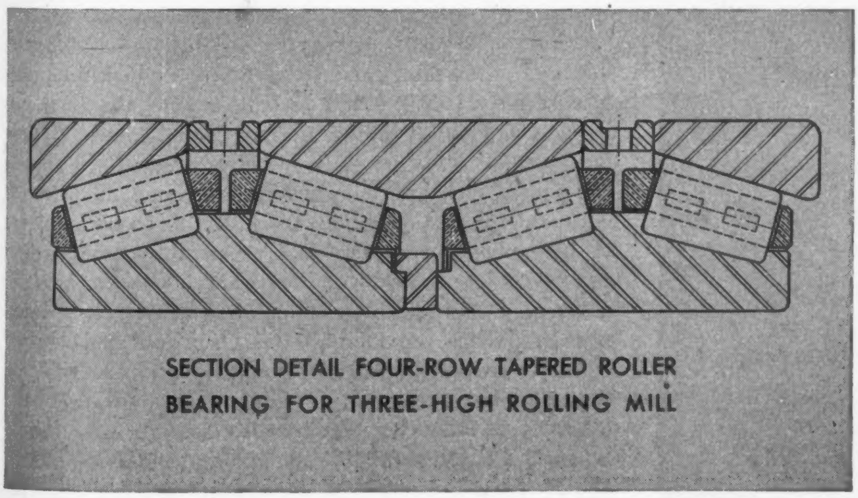
DESIGNATED as the "Micronic" filter because it filters particles of 5 microns and larger, the new precision filter of Adel Precision Products Corp., Burbank, Calif., is now in production for hydraulic systems of large aircraft. Meeting the requirements of Army and Navy specifications, the filter combines high capacity with fineness of filtration and light weight. It operates rfom—65 to 165 degrees Fahrenheit. The filtering cartridge itself expands and contracts with varying temperatures. Model illustrated measures 6 by 8½ inches, weighs 2 pounds, and has 3800 square inches of filtering area. Rated output is 1800 gallons per hour at 100 degrees Fahr., with pressure drop of only 16 ounces, filtering AN-VV-0-366a hydraulic fluid. Inlet opening is 1½ inches in diameter. Filtering flow may be arranged for either direction. To

IN THE NEWS

WITH TORRINGTON BEARINGS

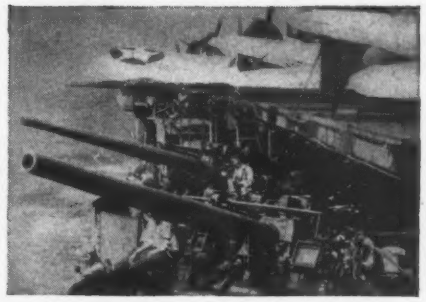


CALIFORNIA STEEL PLANT of Kaiser Company Inc.'s Iron & Steel Division went into operation last fall, rolling out steel sheets and plates for the West Coast industry's needs. This big, three-high rolling mill, built by Lewis-Foundry & Machine, is equipped with four-row tapered roller bearings illustrated below, designed and built by Torrington's Bantam Bearings Division.

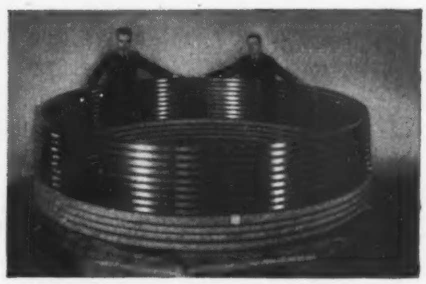


SECTION DETAIL FOUR-ROW TAPERED ROLLER BEARING FOR THREE-HIGH ROLLING MILL

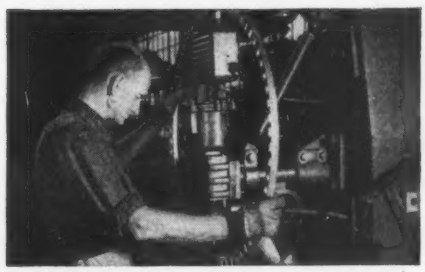
X-SECTION of the 21.500" OD 4-row tapered roller bearing used on the working rolls of the three-high mill shown at top. There are 43 rollers per row. Radial capacity at 100 R.P.M. is 550,000 pounds; thrust capacity, 168,000 pounds. Design and manufacture of large and special bearings to precision and ultra-precision limits is a major part of the service of Torrington's Bantam Bearings Division.



1. THE CURTAIN OF FIRE thrown up by anti-aircraft batteries of our modern Naval units is the most effective ever developed. The extreme accuracy and precision of the gun control mechanisms are aided by the use of anti-friction bearings like those shown below.



2. TEN FEET IN DIAMETER, these are races for gun mount bearings for the 5" twin anti-aircraft guns. Held to tolerances of .002" in diameter, .001" parallelism, Bantam engineers devised special methods for machining and gauging the giant rings where the change of a few degrees in temperature would cause dimensional changes greater than the specified tolerance.



3. RETAINING CAGES STAMPED FROM STEEL were also designed by Bantam engineers to reduce weight, conserve critical material. Shown here is a typical "stamped" cage for 33-inch diameter thrust roller gun mount bearing. Retaining cage for the 10-foot diameter bearings are of similar design, but constructed in eight segments and welded together on assembly. For your special bearing needs, you will find Torrington's experience in the design and manufacture of anti-friction bearings of every major type helpful in the solution of your bearing problems. TURN TO TORRINGTON for your bearing needs.

ARMY E NAVY

TORRINGTON BEARINGS

STRAIGHT ROLLER · TAPERED ROLLER · NEEDLE · BALL

THE TORRINGTON COMPANY · BANTAM BEARINGS DIVISION

SOUTH BEND 21, INDIANA

bypass the full flow of liquid at any predetermined pressure setting, should line surges peak beyond a safe point, an automatic pressure relief valve is incorporated. The filter operates in any position. Dural alloy is used for the metal parts of the filter, although arrangements are made to permit the use of other alloys such as stainless steel for the food industry and other applications. The filter is also available in 4 and 6-inch sizes, with capacities of 900 and 1350 gallons per hour, respectively.

Fluid Metering Pump

FOR general industrial use in pumping light fluids at discharge pressures up to 150 pounds per square inch and for aircraft anti-icing systems for the protection of windshields, carburetors and propellers, Adel Precision Products Corp., Burbank, Calif., has announced its fluid meter pump, Series "K". Its design is predicated on successful aircraft performance of the company's Series "J" fluid-metering pumps. The new series is also a direct drive, rotary-vane-type pump and conforms to the new AN envelope dimensions. It provides accurate metering

of fluid from two discharge outlets, thus making possible the delivery of identical quantities of fluid to two different locations at the same time. Capacities in which the pump is available are: 2.5, 4 and 15 gallons per hour, dual outlet; and 5, 8 and 30 gallons per hour, single outlet. These are nominal values for a discharge pressure of 20 pounds per square inch and 3 inches Hg inlet suction head. It is capable of continuous operation at a discharge pressure of 100 pounds per square inch. Operating temperatures can be as low as —80 degrees Fahr. The pump is for alternating or direct-current operation at 24 volts. Additional capacities provided are from .5 gallons per hour per outlet at pressures up to 500 pounds per square inch and for operation at temperature ranges from —30 degrees to 300 degrees Fahr. Provision is also made for ac-dc operation at 6, 12, 110 and 220, subject to specific requirements. Illustrated is a pump with a capacity of 2.5 gallons per hour, dual outlet, 24 volts direct-current, weighing 2.65 pounds.

Spring-Lock Airplane Fastener

RIGHTS have been acquired by Elastic Stop Nut Corp. of America, Union, N. J., on a new fastener with a spring-lock device invented by Dr. E. L. Mack and perfected by Aircraft Parts Development Corp., Summit, N. J. In addition to its present use on airplanes it is suited to

Information supplied by an Industrial Publication

Not only the quality of steel castings, but their practicability and production cost under ordinary foundry conditions are influenced by design. The following suggestions are offered as an aid to proper design.

1. Whenever possible, all sections should be designed for uniform thickness.

2. Structural design involving abrupt changes in section should be avoided.

3. Sharp corners at adjoining sections should be eliminated whenever possible.

4. When the structure becomes very complicated, it is better to break it into several components that can be cast separately and assembled by welding or bolting.

5. In designing unfed sections in "L" or "V" shapes, it is suggested that all sharp corners at the junction be replaced by radii so that this section becomes slightly smaller than that of the arms.

6. In designing sections that join to make an "X", it is suggested that two of the arms be offset considerably.

7. In the case of unfed "T" and "X" sections, the radii at the junctions should be relatively small.

CLIMAX FURNISHES AUTHORITATIVE ENGINEERING DATA ON MOLYBDENUM APPLICATIONS.

ARMY E NAVY

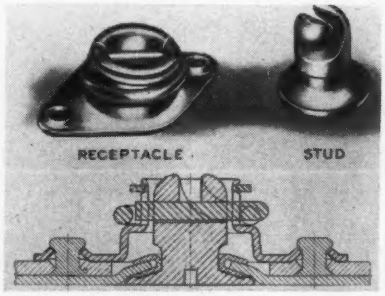
MOLYBDIC OXIDE, BRIQUETTED OR CANNED • FERROMOLYBDENUM • "CALCIUM MOLYBDATE"

MOLY

Climax Molybdenum Company

500 Fifth Avenue • New York City

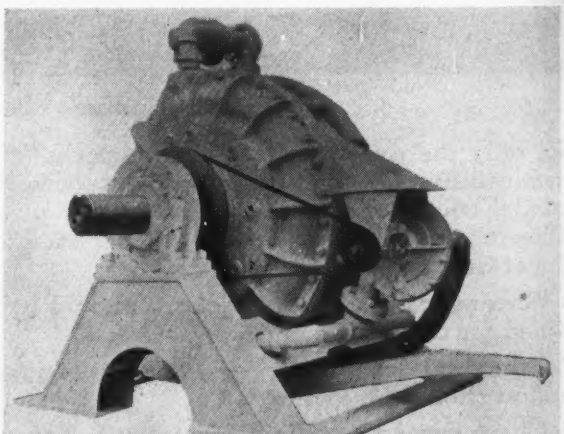
many postwar industrial applications such as farm machinery, motor trucks, home heating units and appliances, radio equipment, and where a quick-acting, vibration-proof, nonrattling fastening is needed. This lightweight



fastener is of rugged construction, particularly suited for holding the engine cowling of high-speed planes. It meets Bureau of Aeronautics' Army Air Force specifications and has been found to meet Navy specifications for aircraft also.

Fluid Friction Controlling Brake

FOR absorbing power by means of fluid friction, the Hydrotarder announced by The Parkersburg Rig & Reel Co., Parkersburg, West Va., can be used on any machine designed with a power take-off shaft and requiring a braking device for controlling or automatically governing the speed of the machine or retarding its speed. The resistance provided by this unit is created by fluid



friction of water as it is circulated. This energy heats the water and is dissipated by the water as it is circulated. Amount of resistance secured depends upon speed of operation of the machine, and is adjusted by regulating the rate of circulation of the water in the Hydrotarder. No mechanical friction or wear occurs and the unit does not operate under pressure. There is only one moving part, the rotor, which operates inside the closed housing which is known as the stator. Typical applications of the Hydrotarder include dynamometers, running-in brakes, brakes for expansion engines, brakes for tension

DESIGN *for Snap Action Switches*

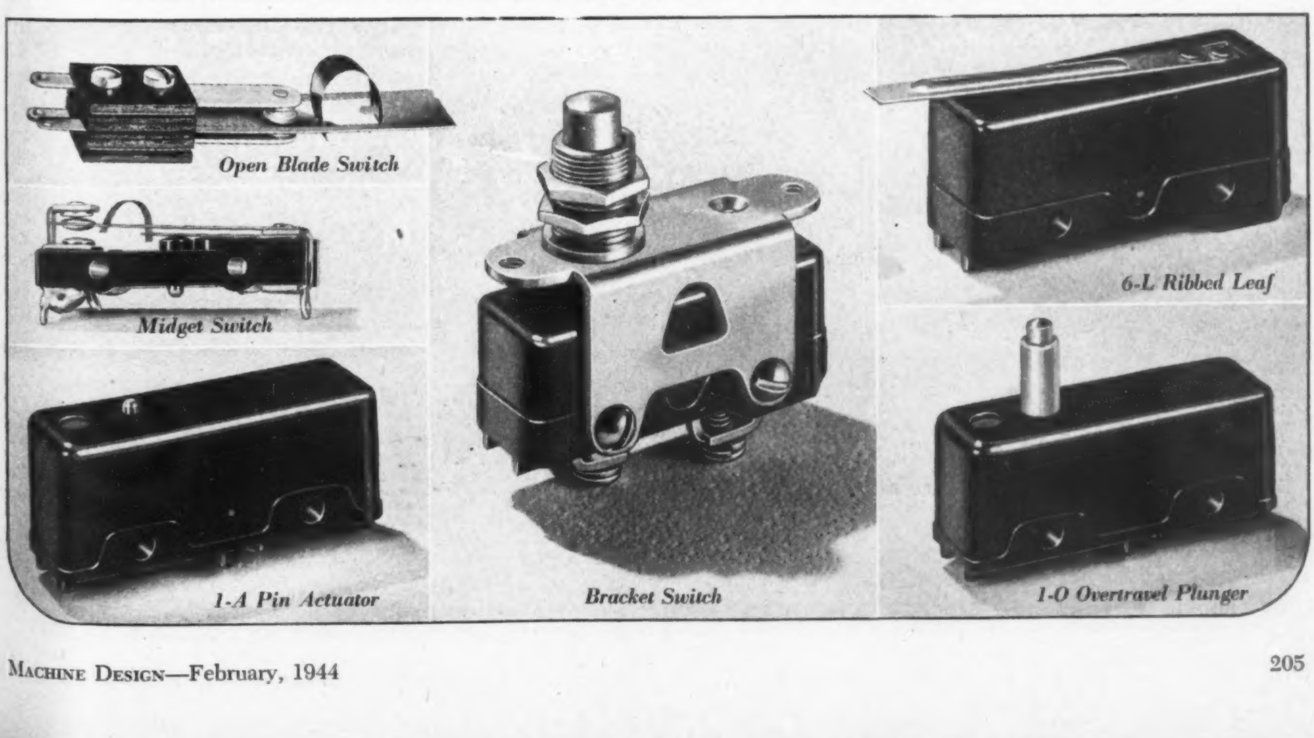
Engineered for FASTER CONTACT BREAK

1. Better contact pressure is maintained until the snap-action is actually begun.

2. The contacts break with maximum accelerating force.

Those two facts account for the rapidly rising preference for ACRO-SNAP SWITCHES. The beryllium spring forces involved are engineered to compel one spring to "Trigger" the other. No matter how slowly the actuating member is operated, the contacts break with optimum acceleration. Careful analysis also shows that good *contact* pressure is maintained until the Snap-Action *suddenly* takes place. But less *operating* pressure is required. That is why smaller coils may be used when it is built into relays. Laboratory tests in industry and record breaking performance on all kinds of war equipment have shown that the Rolling Spring is truly the greatest thing in switches. Furnished in single throw and double throw. In writing, kindly give application details.

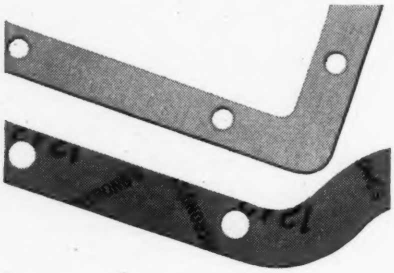
ACRO ELECTRIC COMPANY
1311 SUPERIOR AVENUE CLEVELAND 14, OHIO
NEW YORK, CHICAGO, CLEVELAND, BUFFALO, DETROIT, DALLAS, OMAHA, ST. PAUL, KANSAS CITY, MEMPHIS, TAMPA, BALTIMORE, NEW ORLEANS, PHOENIX, LOS ANGELES, DAYTON, TORONTO, CANADA



reels or rolls, brakes for automotive vehicles and deceleration brakes for spinning machines.

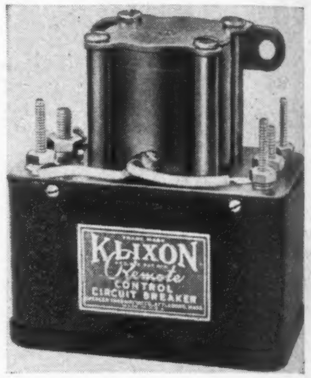
Noncorrosive Gasket Material

FIBER sheet packing in types Nos. 743 and 1242 is being offered by Armstrong Cork Co., Lancaster, Pa. The 1242 packing is a fiber-sheet gasket material for sealing oil, gasoline or water, and is satisfactory for most general gasket applications. No. 743 has been developed to meet a need for a gasket material which will not corrode alloys of aluminum, magnesium, steel, zinc or copper—even in



the presence of moisture or salt spray. Tests indicate that this grade is superior to oil-saturated sheets for applications where a noncorroding material is required. It is made up in rolls up to 50 yards long, in standard widths up to 48 inches. It is also available in sheets and in gaskets diecut to specifications. Standard thicknesses are: .01, .015, .021, .032, .047, .062, .094, .125, and .25-inch, the last three being laminated. No. 1242 packing also is made up in rolls up to 50 yards long, in standard widths up to 48 inches, and in sheets and gaskets diecut to specifications. Standard thicknesses are .015, .031, .062-inch.

Remote-Control Circuit Breakers

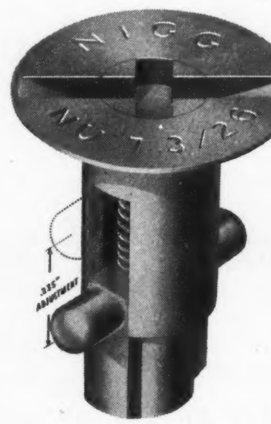


WHILE the new Klixon D-7229, D-7230 and D-7231 remote control circuit breakers were especially designed for aircraft and mobile applications by Spencer Thermostat Co., 34 Forest street, Attleboro, Mass., they are applicable to any operation where control of any remote electrical load is desired. These breaker-relays indicate circuit operation and can readily be reset from a control panel. They are calibrated to precision tolerances and will carry at least 115 per cent of rated current continuously, and will ultimately trip at 125 per cent of rated current in an ambient of 25 degrees

Cent. (77 degrees Fahr.). Actuating element in the circuit breaker is the snap-acting disk which provides a positive make and break. This disk is unaffected by motion, vibration or shock encountered in aircraft and mobile equipment. Available for trip-free or non-trip-free operation, the circuit breaker in the trip-free arrangement opens irrespective of the maintenance of the handle in closed position. In the non-trip-free arrangement, the operator can override the action of the circuit-breaker relays from the control panel. These remote-control circuit breakers are furnished in three sizes with current ratings from 35 to 200 amperes for circuits up to and including 30 volts direct current or 220 volts alternating current.

Self-Adjusting Fastener

INTRODUCED by the Nigg Engineering Co., Covina, Calif., an all-purpose fastener has been developed to meet the Army Air Forces specification AN-F-8 and the Air Service Command requirements for a universal, self-adjusting fastener. It accommodates total sheet thicknesses from .025 to .26-inch, and locks and unlocks with



only a quarter turn. Adjustment is controlled by a central screw which moves a sliding crosspin sleeve through a range of .235-inch, and is made from the outside to any desired tension and locking torque. All outside measurements conform to standard dimensions, making it replaceable with all snap or spring type fasteners. Both in tension and in shear the fastener has exceeded AN requirements.

Plastic Tubing for Electrical Uses

ANNOUNCED by Carter Products Corp., 6921 Carnegie avenue, Cleveland 3, Striatube plastic tubing for electrical insulation, with one or more color stripes extruded in the body of the tubing, makes identification easy. The color stripes—the company's exclusive development in simultaneous plastic extrusion of two or more colors—are an integral part and are as permanent as the body of the tubing itself. Either opaque or transparent tubing can be furnished with one or more contrasting color stripes. The tubing has unusual dielectric

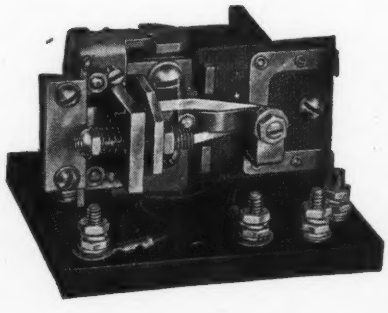
strength and excellent nonoxidizing properties. It is highly resistant to acids, alkalies, oils and greases, and will not deteriorate due to aging or constant exposure to light. Furnished in either flexible or rigid form, it is available in a wide variety of sizes, lengths and thicknesses as well as various degrees of flexibility. Produced by this same process, Striamold plastic molding with decorative color stripes extruded into the body is also announced. Contrasting stripes can be of any color or combination of colors desired.

Monel Metal Floats Offered

MONEL metal floats developed by Chicago Float Works Inc., 2330 South Western avenue, Chicago 8, have been designed to meet the need for corrosion-resistant floats for working pressures up to 300 pounds per square inch and for temperatures up to 750 degrees Fahr. These hollow metal floats are for use in steam traps, liquid level controllers and similar float-actuated mechanisms. Two types of float construction are available, both employing monel metal shells. In one the joint is brazed with high-temperature silver solder, and connection fittings are silver brazed; in the other, the shells are welded with monel metal, and connection fittings are either silver brazed or welded. The silver brazed construction offers a smooth exterior surface. Either of these is furnished in a range of sizes from 2 to 8 inches in diameter, spherical (ball) shape only. Standard brass or monel metal connections in many varieties are available. Floats are also made without connection. In addition to uses mentioned before, these new floats are suited to many applications in the food, chemical and petroleum industry equipment where strength and corrosion resistance are required.

Relay for Varying Current

DESIGNED for a variety of electronic circuit applications where a highly sensitive unit having snap-action contacts is desired, Type 79XAX relay recently introduced by Struthers-Dunn Inc., 1321 Arch street, Philadelphia, operates on as little as 10 milliwatts in its coil circuit. It is recommended for highly sensitive vacuum



tube applications as well as in detecting overloads at low current levels. Its greatest usefulness lies in applications where current varies slowly between various limits, rather

Must it "flex"...freely?

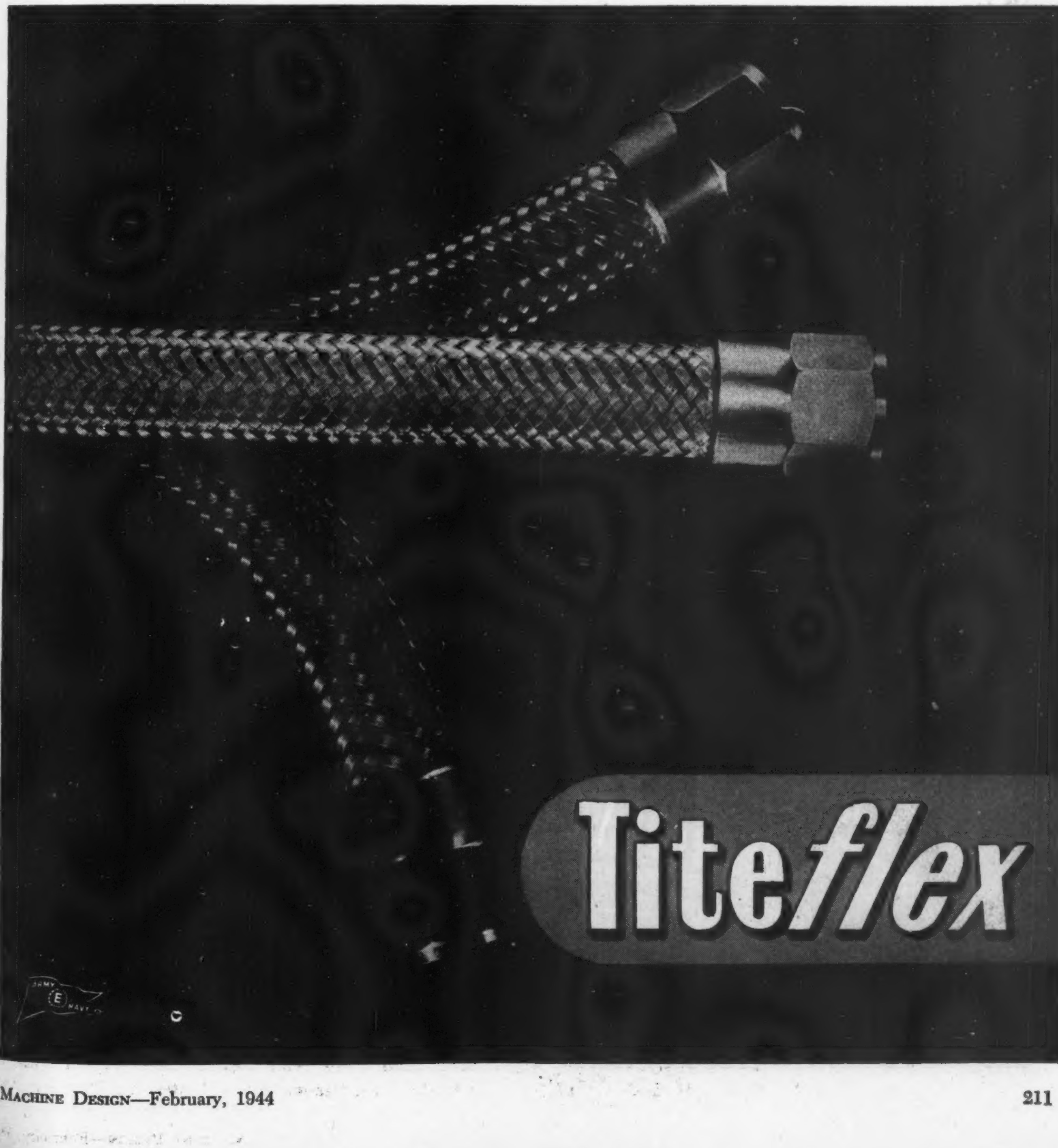
... AND REMAIN PRESSURE TIGHT?

That's the test. Any number of tubings will give you flexibility alone—even a temporary measure of resistance to pressure. But it's the week-after-week, year-after-year ability to "take it" that cuts maintenance and replacement costs to the bone.

• You get that ability in Titeflex metal hose. You get it because Titeflex is all metal—with nothing to disintegrate. You get it because Titeflex has no packed or sliding joints to "let go." You get it—because Titeflex is *proved* tubing, proved under punishing conditions, in the toughest of applications.

• From the wide variety of sizes and fittings, you'll find Titeflex exactly suitable to your present and post-war products. A new 36 page booklet—yours for the asking—gives complete engineering data and specifications. At the same time, the Titeflex staff of engineers will gladly give you the benefits of years of research and experience.

TITEFLEX, INC., 502 Frelinghuysen Ave., Newark 5, N. J.



than quickly from zero to rated value. Contact pressure of this relay remains constant despite slow variations in the coil current in which it is connected. When coil current reaches a certain point, the contacts operate with a positive snap action.

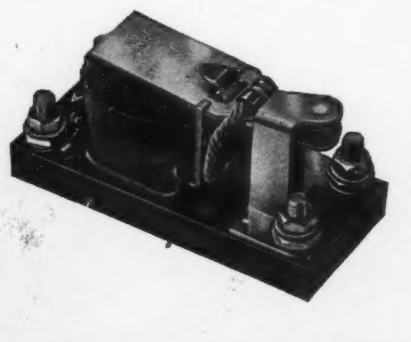
Plastic Insulating Grommets

DEVELOPED by Creative Plastics Corp., 970 Kent avenue, Brooklyn 5, plastic insulating grommets are available in four standardized sizes, for radio, motor and

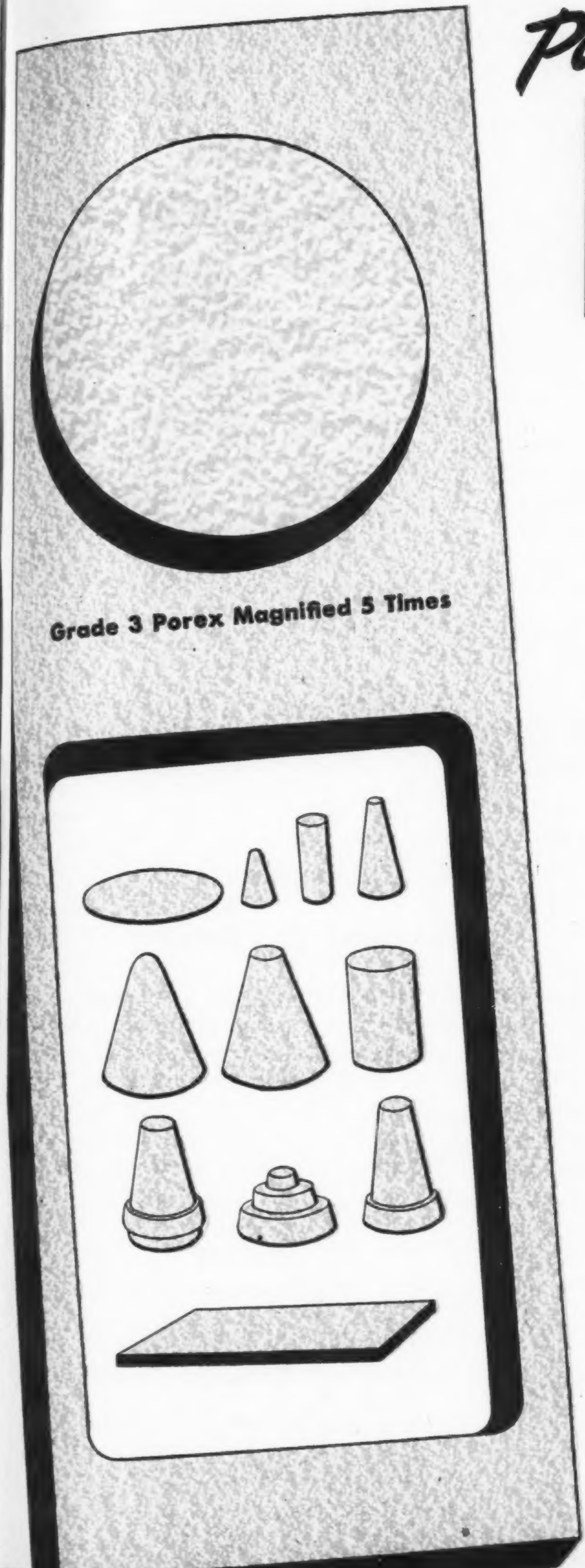
electronic applications. Holes are concentric, with all corners chamfered, avoiding wire chafing. Threads are clean and lubricated, and all parts are matte finished to promote easy gripping and conservation of assembly time.

Shockproof Relay for Aircraft

EXCEEDING all specified requirements for its type of unit, a shockproof relay announced by Struthers-Dunn Inc., 1321 Arch street, Philadelphia, has been designed for rough and tumble airplane use where the ut-



most precaution is taken against unintentional operation of contacts. This relay, designated as Type 17AXX, has withstood acceleration tests of better than 90 gravitational



Put

POREX

to work for you

Porex is made from powdered metal. The primary objective was to produce a better and non-breakable filter. Subsequent developments show that with modifications it can perform specialized functions involved in the flow of liquids and gases.

NEW EFFICIENCY IN FILTRATION—SEPARATION—DIFFUSION—FLOW CONTROL—FLAME ARRESTING AND OTHER FUNCTIONS

Because of its unique structure, Porex presents an exceptionally large number of tortuous passages to any medium passing through it. This characteristic, together with the adaptability of the material to varied shapes and to "press fits," qualifies Porex for service on many applications requiring fine filtration, separation, diffusion and flow control. Wherever fine orifices, precision parts or polished surfaces must be safeguarded against harmful particles–wherever the form, content or rate of flow must be controlled–Porex is a logical solution to your problem.

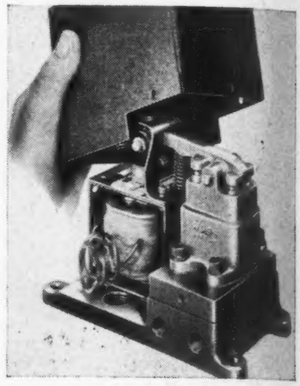
You will want to investigate Porex thoroughly before proceeding with new product designs. It is serving today on well-known products in many fields. Moraine Products Division of General Motors Corporation, Dayton, Ohio.

WAR BONDS SAVE LIVES

MORAINE PRODUCTS
DIVISION OF
GENERAL MOTORS

units, or from eight to ten times the G-rating. Despite the rugged construction, the relay is small in size and light in weight, and is regularly supplied with series coils for any direct current, or with shunt coils for use on 12 or 24 volts direct current.

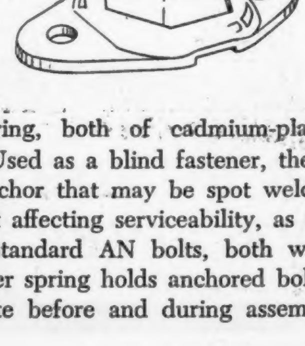
Midget Air Control Valve



OF MIDGET size, the air control valve recently developed by Ross Operating Valve Co., 6485 Epworth boulevard, Detroit 10, can be operated at sustained speeds as high as 400 reversals per minute. This compact solenoid air-control valve, known as Model 835, is a ¼-inch heavy duty, 4-way valve for controlling double-acting cylinders. It can also be employed as a 3-way valve by plugging one outlet. Using the same poppet-type principle that the company has been using in its other valves, the Model 835 is 7 inches long, 3½ inches wide and 5¼ inches high. Its other features are low-current consumption, noiseless operation and long life.

Nut and Bolt Retainer

PRODUCED by Kaynar Mfg. Co., Los Angeles, a new type of nut and bolt retainer will be of interest to designers of aircraft, marine or ordnance equipment. It is interchangeable with present types of anchor fittings, except where slightly greater width would cause interference. Approved by the United States Army Air Corps and C.A.A., the design consists of a retainer plate and



a retainer spring, both of cadmium-plated tempered spring steel. Used as a blind fastener, the retainer provides a nut anchor that may be spot welded to the assembly without affecting serviceability, as well as a bolt anchor using standard AN bolts, both with axial flexibility. Retainer spring holds anchored bolt head or nut in retainer plate before and during assembly. Conver-

sion of nut plates to blind studs is also permitted without tooling change while part is in production. Easy removability eliminates the problem of stripped nut removal and allows the use of dural nuts in certain applications. Attaching dimensions of the new fastener are held to .002-inch which eliminates line drilling of assemblies and permits prefabrication of holes.

Heavy-Duty Swivel Caster

ALL-STEEL, heavy-duty casters announced by Rose Mfg. Co., 12400 Strathmoor, Detroit, feature in their design a drop-forged base plate with king pin integral. On the axle is a hardened nonturning spanner bushing and

a roller wheel bearing. The caster swivels on ⅜-inch chrome steel ball bearings that ride in removable (heat-treated) steel races. This latest design of caster developed by the company, is offered in eight different types.

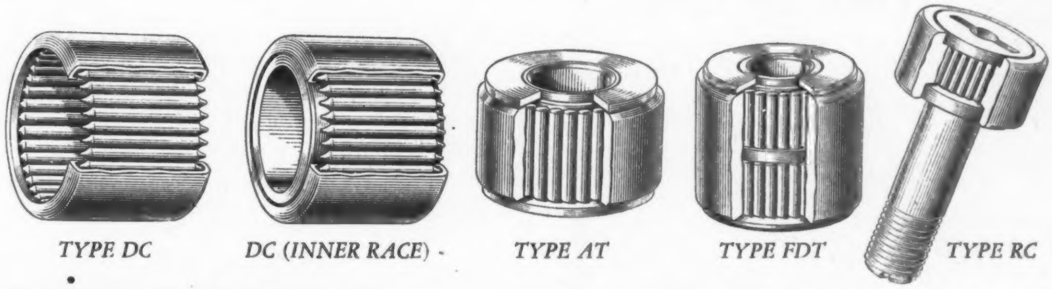
Airplane Skin Fasteners

TO CUT the accident hazard in the use of airplane skin fasteners, two new safety developments have been made by the Prestole Division of the Detroit Harvester Co., Toledo. Approved by the National Safety Council, the first of these developments is the addition of a cap to the conventional fastener preventing retrograde movement of the spring and fastening element in the event of failure, thus eliminating the hazard of flying parts. The second is a redesign of its Prestite Safety gun so that the plunger which actuates the fastener extends within the cup, eliminating the possibility of the fastener shooting out of the gun or becoming disengaged due to improper placing of the fastener in the inserting tool.

Self-Sealing Coupling

AVAILABLE with AAF and AN threads, a disconnecting self-sealing coupling, the latest development of American Screw Products, 7000 Avalon boulevard, Los Angeles 3, is said to withstand 2500 pounds per square inch after finger-tightening. Tests under severe han-

These Needle Bearings ALL Have High Unit Capacity!



TYPE DC • *DC (INNER RACE)* • *TYPE AT* • *TYPE FDT* • *TYPE RC*

HIGH LOAD RATING IN PROPORTION TO SIZE AND WEIGHT IS IMPORTANT DESIGN FEATURE

•

As new applications have developed requiring a small size, lightweight, high capacity, anti-friction bearing, modifications have been made in the original Torrington Needle Bearing design until today a full line with a wide range of types and sizes is available.

All of these Needle Bearings offer the outstanding advantage of high unit capacity.

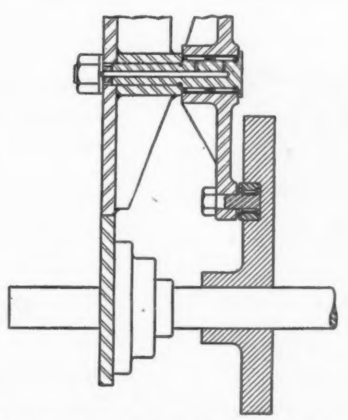
Their high radial load-carrying capacity is due to their basic design principle: A full complement of small diameter needle rollers held within a retaining raceway to form a single compact unit. Thus, in small space, more than double the "line contact" is provided than in other radial roller bearing types.

Weight distribution within the bearing's "load zone" is spread over a larger "area" and danger of stress concentration on races or rollers is consequently reduced.

"Heavy Duty" Types

Many of the newer types of Torrington Needle Bearings have been designed to utilize the full non-Brinell capacity available. For example, the FT Type is provided with a permanently attached inner race, hardened to a depth to carry the rated load of the bearing. The outer race is heavier and designed to serve without an auxiliary housing if desired.

Similarly, other RC Types for use primarily in the application of Needle Bearings as cam followers, have a heavy outer raceway and are designed for heavy rolling loads. Maximum static non-Brinell capacities extend from 1,410 to 133,600 pounds which provide the design engineer with a wide range in bearing selection. The Torrington Engineering Department should be consulted for capacity under rolling loads. Additional information will be found in our Catalog No. 109, available on request.



Application of the Type RC Needle Bearing in cam follower service and two DC Needle Bearings on rocker shaft are shown in this cross-section of a package sealing machine.

A Unique Combination of Advantages

All types of Torrington Needle Bearings offer the same outstanding advantages which gave the original unit such immediate and widespread acceptance. In addition to high capacity, they are small in size, light in weight. Their unit construction adapts them to mass production methods of assembly. They are easily and efficiently lubricated. And they are low in cost.

All these features are important in planning designs for today's needs and for "Tomorrow's" demands when reduced size, weight and cost will be important factors in contributing to increased production, distribution *and* operating efficiency. Our engineering staff will gladly work with you in selecting the Needle Bearing and in laying out applications.

THE TORRINGTON COMPANY

Established 1866 • Torrington, Conn. • South Bend 21, Ind.

"Makers of Needle Bearings and Needle Bearing Rollers"

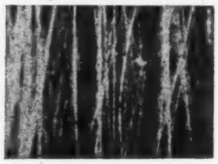
New York · Boston · Philadelphia
Detroit · Cleveland · Seattle
San Francisco · Chicago · Los Angeles
Toronto · London, England

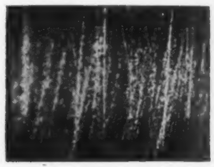
TORRINGTON
NEEDLE BEARINGS

dling conditions have shown that the heavy construction of the aluminum alloy body prevents distortion, and that jamming of the spring-loaded shut-off valve is prevented. Springs are heat-treated steel. Lightweight cast phenolic poppets are positive-sealing in action. A leakproof connection is provided by a synthetic gasket when coupled for service.

High Precision Surface Finish

DEVELOPED by Engis Equipment Co., 310 South Michigan avenue, Chicago, the new Hyprez finish is primarily for internal and odd shapes working with special carriers and abrasives of high quality and fineness. This finish for surfaces prepared by machining, grinding, honing or lapping, presents a uniform appearance without the pronounced scratch pattern. It is being applied to ball





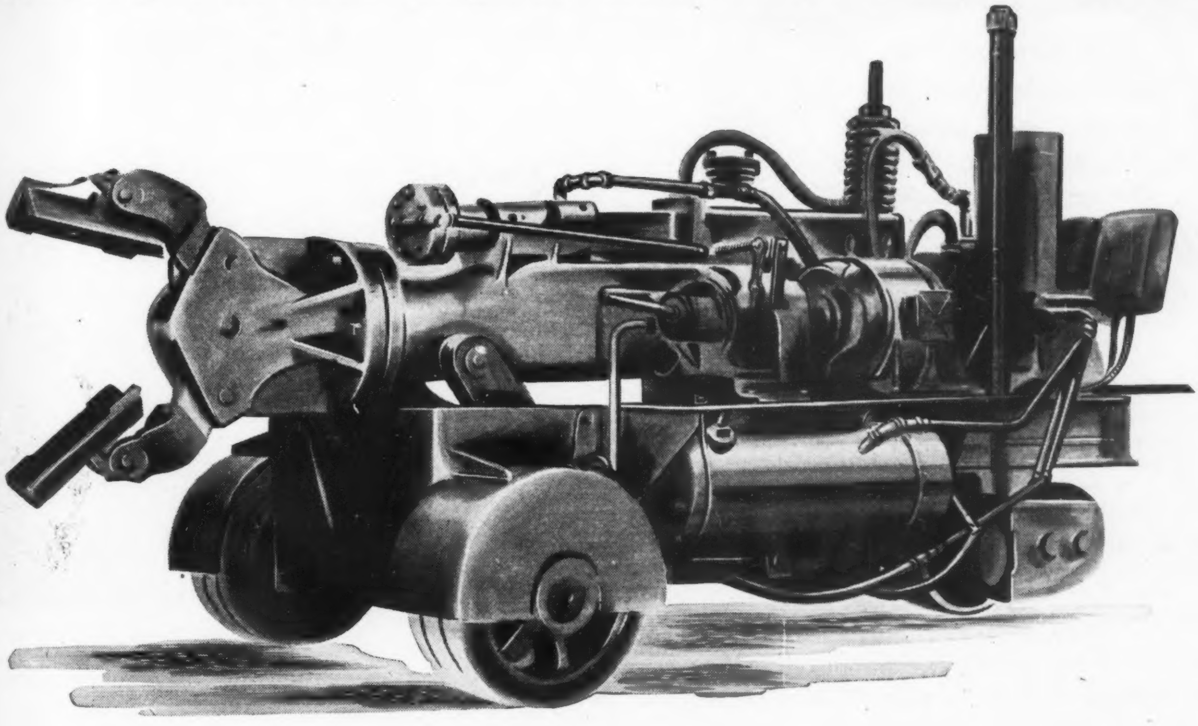
bearing races, instrument pivots, cartridge case dies, gears (bores), hydraulic cylinders, etc., and is indicated wherever frictionless movement is required. Particularly adaptable to straight and tapered holes or bores, and to contours such as ball shapes, cones, etc., this process is used on surfaces that are difficult to finish by any other method. Amount of stock to be removed varies with quality of surface before finishing, the depth of its deepest imperfection, and the hardness and quality of the piece. The company is prepared to apply this finish, known as Hyprez, on parts already made, or to supply complete Hyprez finished parts.

Ready-To-Set Glass V-Jewels

GLASS V-jewels are being furnished by General Electric Co., Schenectady, N. Y., to replace imported sapphire jewels which have become practically unobtainable. To save the user inspection time, the glass V-jewels are examined under a binocular microscope for incipient flaws, the depth of the "V" and its concentricity, and are explored for pits or roughness with a fine steel needle. Following inspection and before shipment, all jewels are cleaned in three positions in a special watch-cleaning machine and spun dry for five minutes between each position. Improvement has been made in the glass as compared with that previously used. These jewels will resist shocks in excess of those required to damage instrument steel pivots, as the glass jewels are specially designed for this application. They are used in small panel instruments with a moving system which weighs one gram or less. The jewels have the same coefficient of friction as the sapphire and in combination with instrument steel pivots, under vibration, they often produce less friction increase than does the sapphire. Sizes of the glass V-jewels are .051 and .076-inch.

The "PINCER MOVEMENT" with the MOTHER'S TOUCH

executed with the help of HELE-SHAW FLUID POWER



Machines like this have a big job . . . handling 2,000 to 20,000 lb. ingots in and out of furnaces, and holding them under forging hammers.

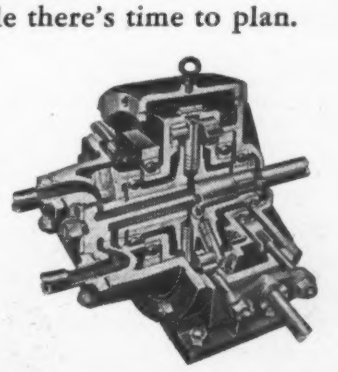
It's a mobile Auto Floor Manipulator, designed and built by Edgar E. Brosius, Inc. The business end rotates, raises and lowers; the powerful jaws open and close. These movements are energized by Hele-Shaw Fluid Power; that is, oil under pressure, from a Hele-Shaw Pump. Hydraulic operation eliminates individual motors, makes a compact machine. Tremendous sustaining pressure on the tongs prevents the billet from dropping, yet the billet can be manipulated as tenderly as a mother handles a new born baby.

Among your machines or equipment for future release may be operations such as pulling, pushing, stretching, squeezing, lifting, tilting, or many others, which Hele-Shaw hydraulic engineers can improve. Find out now while there's time to plan.

THE

Hele-Shaw

Fluid Power Pump



OTHER A-E-CO PRODUCTS: TAYLOR STOKERS, MARINE DECK AUXILIARIES, LO-HED HOISTS

AMERICAN ENGINEERING COMPANY

2502 ARAMINGO AVENUE • PHILADELPHIA 25, PA.

MEN OF MACHINES

RECENTLY made vice president, director and chief engineer, E. J. Sanders brings a wide fund of experience to his work of directing design and installation of units produced by Kontrol-Fan Inc., Los Angeles, at the present time active in special government work and in producing thermostatically-operated, controllable-pitch blade fans for gasoline, natural gas and diesel engines and other industrial equipment. Before becoming connected with the Kontrol-Fan company, Mr. Sanders had been equipment engineer with J. E. Haddock Ltd. Previously he carried out extensive road and high-speed tests, contributing substantially to the progress of controlling engine temperatures, for the Gilmore Oil Co. Mr. Sanders was engaged as mechanical engineer for several California oil companies, prior to 1929, concerning himself principally with natural gas engine-driven compressors.

◆

IN HIS new capacity as engineer for the Timken - Detroit Axle Co., Detroit, H. E. Simi will put to worthwhile use his past engineering experience in the automotive field. A graduate of the University of California in 1922, Mr. Simi worked for the Westinghouse Pacific Coast Brake Co. as development engineer on the automotive air brake in its early days. In 1927 he joined Fageol Motors, Oakland, Calif., as truck engineer and carried out special work on buses and air brakes. During the latter part of 1926 he did some private design work, which turned out to be the beginning of the original twin engine coach and what is now known as the Metropolitan type of construction body. The design of the hoodless bus with body built integral with the chassis was so success-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ful that in 1927 this company started to manufacture a vehicle of this type in Kent, O., where Mr. Simi acted as chief engineer. He remained there until 1943 when the bus manufacture was terminated and the company entered aircraft parts work on a subcontract basis. For a period of six months in 1943 Mr. Simi worked with the C. L. Gaugler Machine Co. and helped set up an engineering department procedure for them. He then joined the Timken company as project engineer.

♦

APPOINTMENT of Lawrence B. Jackson as director of engineering of the diesel division of American Locomotive Co. has recently been announced by Duncan W. Fraser, president of the company. Widely known through his contributions to various technical journals on subjects relating to internal combustion engines, Mr. Jackson is a graduate of Stevens Institute of Technology. After being associated with the American Hawaiian Steamship Co. as superintending engineer and with the Texas Steamship Co. in various capacities in the technical division of the marine department, he became associated with Fairbanks, Morse & Co. in 1925. In this organization he advanced through the ranks of engineer, assistant chief engineer, and chief engineer of the diesel division, to manager of marine diesel sales. In 1936 he was promoted to the position of manager of engineering. Mr. Jackson is the inventor of an interlock hydraulic control for water gas manufacturing and an exhaust silencer. He is a member of the American Society of Mechanical Engineers, Society of Automotive Engineers, Society of Naval Architects and Marine Engineers, and the technical committee of the American Bureau of Shipping.

♦

LEON R. LUDWIG, formerly head of the Westinghouse Electric & Mfg. Co. circuit breaker and protective devices division, has been made manager of the motor division of the company. He is a holder of more than a score of patents, and has worked with DR. JOSEPH SLEPIAN, associate director of the Research Laboratories, to develop the Ignitron.

♦

DOUGLAS E. HOWES, professor of electrical engineering, has joined the staff of the radio research laboratory at Harvard university, Cambridge, Mass.

♦

FERNLEY H. BANBURY will act in a consulting capacity for the Banbury Mixer department of Farrel-Birmingham Co. Internationally known for his invention of the Banbury mixer which has revolutionized mixing processes in rubber and plastics plants, Mr. Banbury is retiring from

active management of the Banbury Mixer department. He has been connected with Farrel-Birmingham Co. for twenty-seven years.

♦

Reuben H. Fleet has been elected president of the Institute of Aeronautical Sciences for 1944. Mr. Fleet is consultant for Consolidated Vultee Aircraft Corp., Lindbergh Field, San Diego, Calif.

♦

Edward J. Partington has been transferred to Bendix Aviation Ltd., Hollywood, Calif., as development engineer. He had been located at the Bendix Products division at South Bend, Ind.

♦

C. L. McGranahan has been elected president of the Association of Iron and Steel Engineers, and will assume office January 1. Mr. McGranahan is assistant general superintendent, Jones & Laughlin Steel Corp.

♦

John A. Hutcheson, for the past three years manager of engineering, Baltimore Radio division, Westinghouse Electric & Mfg. Co., has been made associate director of Westinghouse Research Laboratories.

♦

Carl Luth has been appointed chief engineer, Duquesne works, Carnegie-Illinois Steel Corp., Pittsburgh, with Gustave G. Erland as assistant chief engineer. J. N. Von Behren is chief engineer of the company's Pittsburgh district.

♦

D. A. Milligan has joined Harry Ferguson Inc., Dearborn, Mich., as director of research. He continues as consultant to the Farm Machinery division, War Production Board. Formerly Mr. Milligan was connected with Cleveland Tractor Co.

♦

William E. Gray has resigned after 17 years as head of the draft gear research program at Purdue university to become vice president in charge of Peerless Equipment Co., Chicago. Prof. T. K. Sanders, a member of the Purdue mechanical engineering faculty, will succeed Mr. Gray in the draft gear program.

♦

Nathaniel E. Warman, formerly marine engineer of Marinship Corp., where he was in charge of designing machinery for tankers, has joined Ryan Aeronautical Corp., San Diego, Calif., as assistant to the chief engineer.

♦

Delos M. Palmer, dean of engineering at the University of Toledo since 1934, has joined the American Propeller Corp., subsidiary of the Aviation Corp. of Toledo, O.

♦

H. H. Friend is the new development engineer of electronics for the airplane division department of Curtiss Wright Corp., Bloomfield, N. J. Mr. Friend was formerly associated with Scintilla Magneto division, Bendix Aviation Corp.

♦

Walter J. Ewbank is the new chief engineer of Briggs Clarifier Co., Washington, D.C. Since joining the company in 1938, Mr. Ewbank has held the positions of head of the chemical laboratory, assistant chief engi-

RIVERSIDE BERYLLIUM COPPER

The Ideal Alloy for Springs

The Riverside Metal Ccmpany announced the production of Beryllium Copper in 1933. Immediately the possibilities of Riverside Beryllium Copper as an outstanding spring material aroused the attention of the engineering world. But it took the ability of wrought Beryllium Copper to meet the highly exacting specifications of the Army, Navy and Air Corps to broaden its use. For, as a spring material, Beryllium Copper offers extraordinary advantages because of the invaluable properties it possesses: High fatigue strength, elastic limit and hardness; relatively high tensile strength and electrical conductivity; excellent corrosion and wear resistance; good resistance to room temperature creep and to galling against steel, plus a fabrication advantage which permits good formability of intricate parts and their subsequent hardening—to an unprecedented degree—by a simple heat treatment. Riverside Beryllium Copper is now being used for spring purposes in aircraft, ships, tanks, guns, instruments, engines, motors, radios, telephones, telegraph and electrical control equipment for machinery and fire equipment. Riverside engineering and laboratory service is most important in cooperating with the development of devices where the use of Beryllium Copper springs are indicated, because it represents years of progressive pioneering in solving such problems. Riverside Beryllium Copper meets the requirements of A.S.T.M., B120-41T.

Right now, more and better information on the use of wrought Beryllium Copper—for war or post-war products you are planning to manufacture—is available through the greatly extended research facilities of our technical staff.

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neer, and manager of research and development, the latter prior to his recent appointment.

♦

Clarence C. Helmle will be engaged in plating equipment design, process development, and technical service for the Enthone Co., New Haven, Conn.

♦

Victor R. Willoughby, vice president, American Car & Foundry Co., New York, formerly in charge of engineering, has been made director of research and development. Edmund D. Campbell, recently appointed vice president, succeeds Mr. Willoughby as head of the company's engineering activities.

♦

W. S. James, chief engineer, Studebaker Corp., has been nominated as president of the Society of Automotive Engineers Inc. for 1944.

♦

John Dolza and Harry C. Karcher of the Allison Division, General Motors Corp., Indianapolis, have been awarded the Manly Memorial medal of the Society of Automotive Engineers.

♦

Jack E. Davis is connected with the Army Air Forces, Mid-Central Procurement District, as mechanical engineer in charge of technical control work for the Army at the Dodge Chicago plant. He also is an evening instructor at Illinois Institute of Technology, where he is teaching aircraft-engine power measurements.

♦

C. W. Musser has joined the relay division, Allied Control Co. Inc., Chicago, as chief engineer.

♦

J. B. Macauley Jr. has joined Pratt & Whitney Aircraft, Division of United Aircraft Corp., East Hartford, Conn., in its engineering department. He formerly was research engineer at the Chrysler Corp. in Detroit.

♦

Richard C. Aland, after a short leave of absence, has returned to assume his duties as engineer in charge of design in the newly created New Engines department of Continental Motors Corp. Mr. Aland has been connected with the company for the past several years as designer and project engineer on aircraft engines.

♦

Noel J. Lituchy has become connected with the Collins Radio Co., Cedar Rapids, Ia., as mechanical development engineer. He formerly was an ignition engineer in the engine department, Allis division, General Motors Corp.

♦

Britt M. Smith, formerly chief engineer for Yates Aircraft Corp., Beaverton, Oreg., has been appointed senior development engineer, Goodyear Aircraft Corp., Akron, O.

♦

John Walker has been transferred from the Allentown, Pa. office of the Mack Mfg. Corp. to the New York office, and retains his position as assistant chief engineer.

♦

Seth Johnson, who formerly had been an engineer with the Republic Aviation Corp., Farmingdale, L. I., N. Y., is now with the Kellet Autogiro Corp., Upper Darby, Pa., as production design engineer.

PREVENT TOMORROW'S HEADACHES TODAY...

Tomorrow's headaches will be the sudden need for new machines, new tools, and new products that are not even designed.

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Let's have no headaches, unnecessarily! *Today's remedy for both situations* is to call upon the 220 engineers, designers, tool makers, draftsmen and technical experts who comprise Siewek Engineering Division. At any point from bare idea to manufacturing set-up, this nationally known organization is prepared to bring brains, skill and broad experience to your service. Whatever your problem involves, Siewek stands qualified *and prepared* to solve it.

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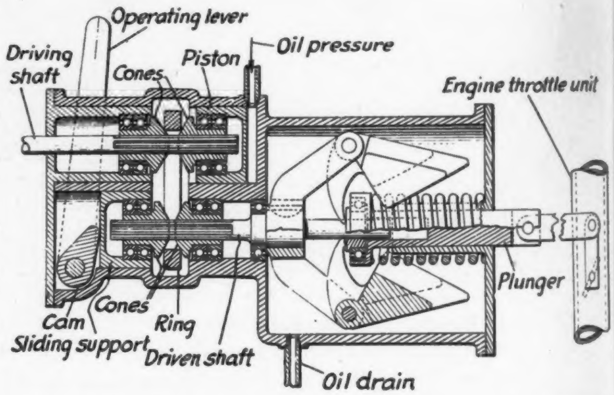
Noteworthy Patents

Governs Over Wide Speed Range

MECHANICAL governors of conventional design, capable of limiting engine speed to a predetermined maximum, usually are effective only at engine speeds which rotate the governor weights at speeds developing sufficient centrifugal force to overcome the resistance of the throttle. In a new design, covered by patent 2,334,720 recently granted to John W. Marsh of the United States Army, provision is made for controlling engine speed over the entire speed range of the engine. Such control permits application of load to the engine without manual manipulation of the throttle, without stalling and without the necessity of operating the engine at speeds deleterious to the clutching mechanism.

As shown in the accompanying drawing, the foregoing objectives are accomplished by operating the governing mechanism through a controllable variable speed ratio changing device. The governor itself is of the centrifugal



By driving centrifugal spring-loaded governor at variable speed, effective control over a wide range of engine speeds is obtained. Governed speed is set by operating lever

spring-loaded type operating directly on the engine throttle. The driving shaft, which runs at a speed proportional to that of the engine, drives the revolving flyweights of the governor through an adjustable cone and ring speed changer. On the driving shaft the left-hand cone is so mounted in the housing that axial movement is prevented, while the right-hand cone is carried in a piston which is free to slide axially. Oil pressure from the lubricating system of the engine is supplied to the right-hand side of the piston, thus maintaining a constant force which urges the two cones on the driving shaft toward each other. On the driven shaft the right-hand cone is prevented from axial movement while the left-hand cone is carried in a sliding support which is maintained in any desired position by means of a cam bearing against the support.

(Continued on Page 232)

Double-reduction worm gear for vertical drive; the driven shaft may extend up or down.

Double-reduction worm gear for horizontal drive

De Laval double-reduction worm gears are made in ratios from 50 to 1 up to 8000 to 1.

A rigid cast iron housing maintains the worms and worm gear in perfect alignment, serves as an oil well, protects the working members from dirt and moisture, and eliminates danger to operatives.

There are only three working members, namely, the high-speed worm, the gear with which it engages and which is mounted upon the slow-speed worm, and the slow-speed gear and shaft.

The high-speed gear and the slow-speed worm dip in a reservoir of oil, lubricating all tooth and thread contact surfaces, while the ball bearings supporting both the high-speed and the slow-speed worms are immersed in oil. The slow-speed gear bearings are amply proportioned and effectively lubricated to withstand the considerable forces involved in a high-ratio reduction.

De Laval single-reduction worm gears are built for ratios from 4 to 1 up to 100 to 1 and for either horizontal or vertical drives.

1140

De Laval **Worm Gear Division** of the De Laval Steam Turbine Co., Trenton 2, N. J.

MANUFACTURERS OF TURBINES . . . STEAM, HYDRAULIC, PUMPS . . . CENTRIFUGAL, CLOGLESS, ROTARY DISPLACEMENT, MOTOR-MOUNTED, MIXED-FLOW, PROPELLER; PRIMING SYSTEMS; CENTRIFUGAL BLOWERS and COMPRESSORS, GEARS WORM, HELICAL, and FLEXIBLE COUPLINGS

(*Continued from Page 228*)

the cam position being controlled by an operating lever.

When the operating lever is moved toward the left, oil pressure urges the right-hand driving cone toward the left, causing the driving ring to ride nearer the periphery of the cones and in turn to wedge the driven cones apart as it rides toward the inner radius of the latter. This movement persists until the sliding support is stopped by the cam. In this position the governor is driven at high speed and therefore exerts control at a low engine speed.

Controlling at High Speed

For control at high engine speed the operating lever is moved toward the right, forcing the driven cones together and the driving cones apart against the oil pressure. The governor is then driven at a low speed relative to the engine.

Under normal operating conditions the governor plunger is in equilibrium, being acted upon by a force to the left from the compression spring and a force to the right from the arms attached to the flyweights. Increase in speed causes centrifugal force to increase, forcing the plunger to the right and closing the throttle. Decrease in speed allows the spring force to overcome the centrifugal force, permitting the plunger to move to the left and open the throttle.

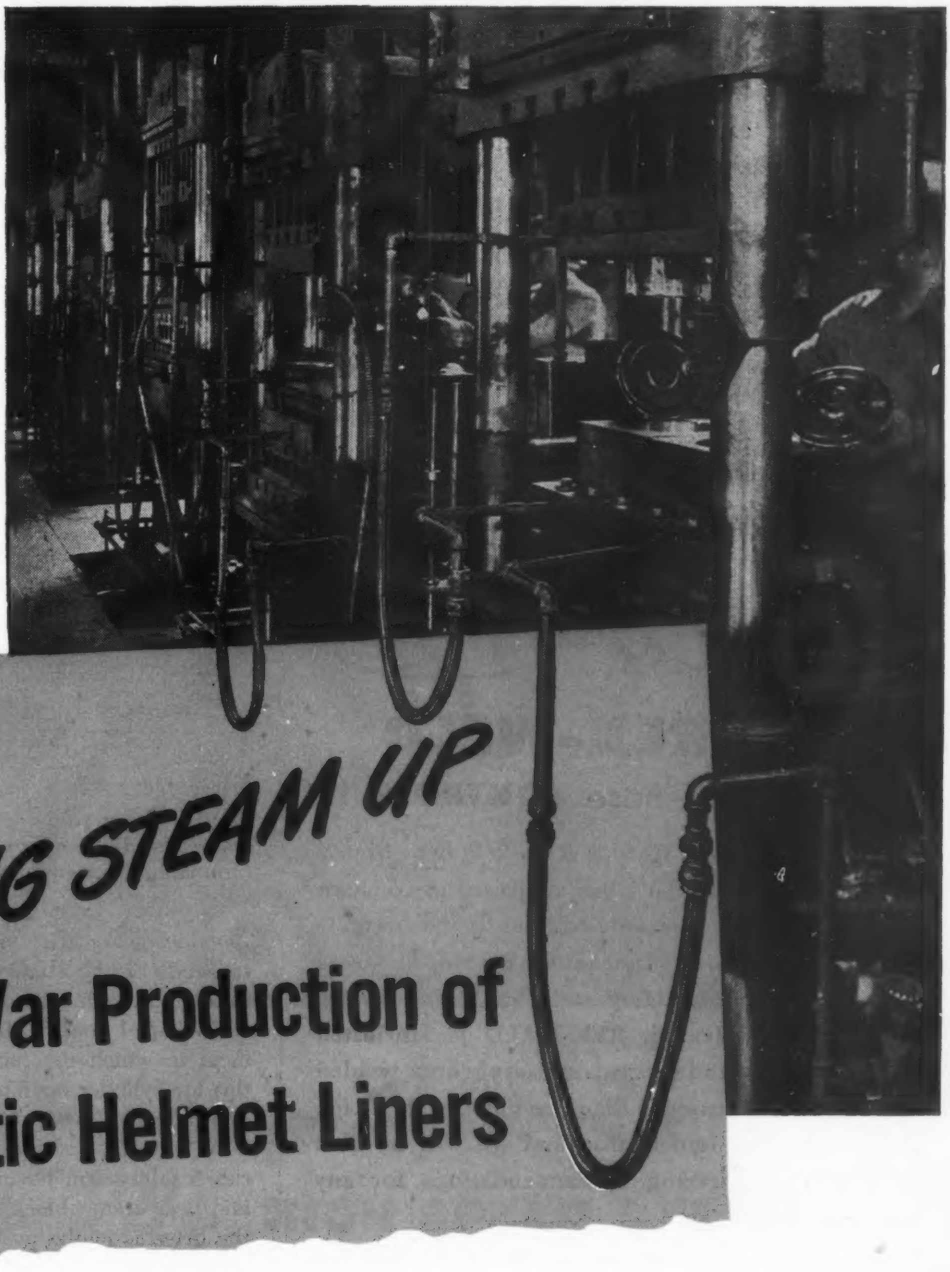
Lubrication of the speed-changing and governor mechanism is effected by allowing escape of oil past the piston into the housing, whence it flows through a drain outlet to the sump.

Provides Intermittent Rotation

IN DRIVING mechanisms for glass-forming machine turrets, it is desirable that the turrets be intermittently driven in timed relation at the same speed but in opposite directions. The parison mold on one turret must accurately line up with the finish mold on the other for transfer of the parison during the dwell period. Difficulties in maintaining the necessary accuracy, due to wear of teeth in gear trains as well as wear of bearings prompted the development of the simplified design described in this article and covered by patent 2,334,684, recently assigned to Fairmount Glass Works Inc.

Upper view in the accompanying illustration shows the driving mechanism in plan. Each turret spindle carries a ring gear; the two gears, however, are at different elevations as shown in the two sectional views at the lower part of the figure. The gears are driven by a set of racks *A*, *B*, *C*, and *D*, which are reciprocated by means of a piston operating in an air cylinder shown at right of the plan view. Adjacent ends of aligned racks *A*, *C* and *B*, *D* are supported and connected by clamps forming part of a carriage mounted for reciprocation upon a supporting rod.

In the position shown rack *A* engages the right-hand gear, rack *D* engages the left-hand gear and the racks are moving from right to left, rotating the turret spindles in the direction shown by arrows. The racks *B* and *C* are out of engagement, as shown in the end views at the lower part of the figure. When the racks reach the end



KEEPING STEAM UP for War Production of Plastic Helmet Liners

Way back in the relatively calm days of '39, the Molded Products Company of Chicago were making radio cases for the pleasure of ordinary citizens. In May of that year they equipped one press with steam connectors of American Flexible Seamless Tubing. In September they equipped two more presses. In March 1940, under the pressure of war contracts, they equipped additional presses. And in July 1942, with the plant on 100 percent war production of helmet liners and plastic wheels for hand trucks, the remaining presses were given the added security of these steam-tight, free-moving, long-lived connectors.

The experience of the Molded Products Company is but one more instance of American Metal Hose going in on trial . . . *and coming out on top.* Wherever a practically indestructible, flexible, air-tight conveyor is required, for oil, gas, or water; for vacuum service or for protecting electric wiring, American Flexible Metal Hose and Tubing are providing reliability and economy.

44191

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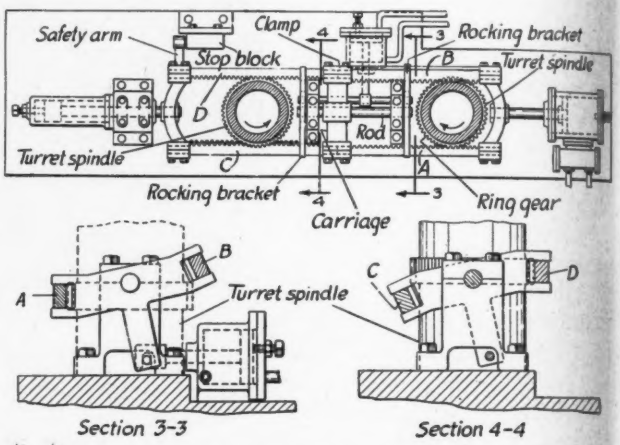
American Metal Hose

of their stroke there is a dwell during which the transfer of the parison from one turret to the other is effected. On the return stroke the racks *A* and *D* are moved out of engagement with their corresponding gears while the racks *B* and *C* are brought into engagement. Hence, as the racks move from left to right the turret spindles are again rotated in the direction shown by the arrows.

As shown in the lower views the aligned racks *A*, *C* and *B*, *D* have a relative angular displacement, one being engaged while the other is out of mesh with its corre-

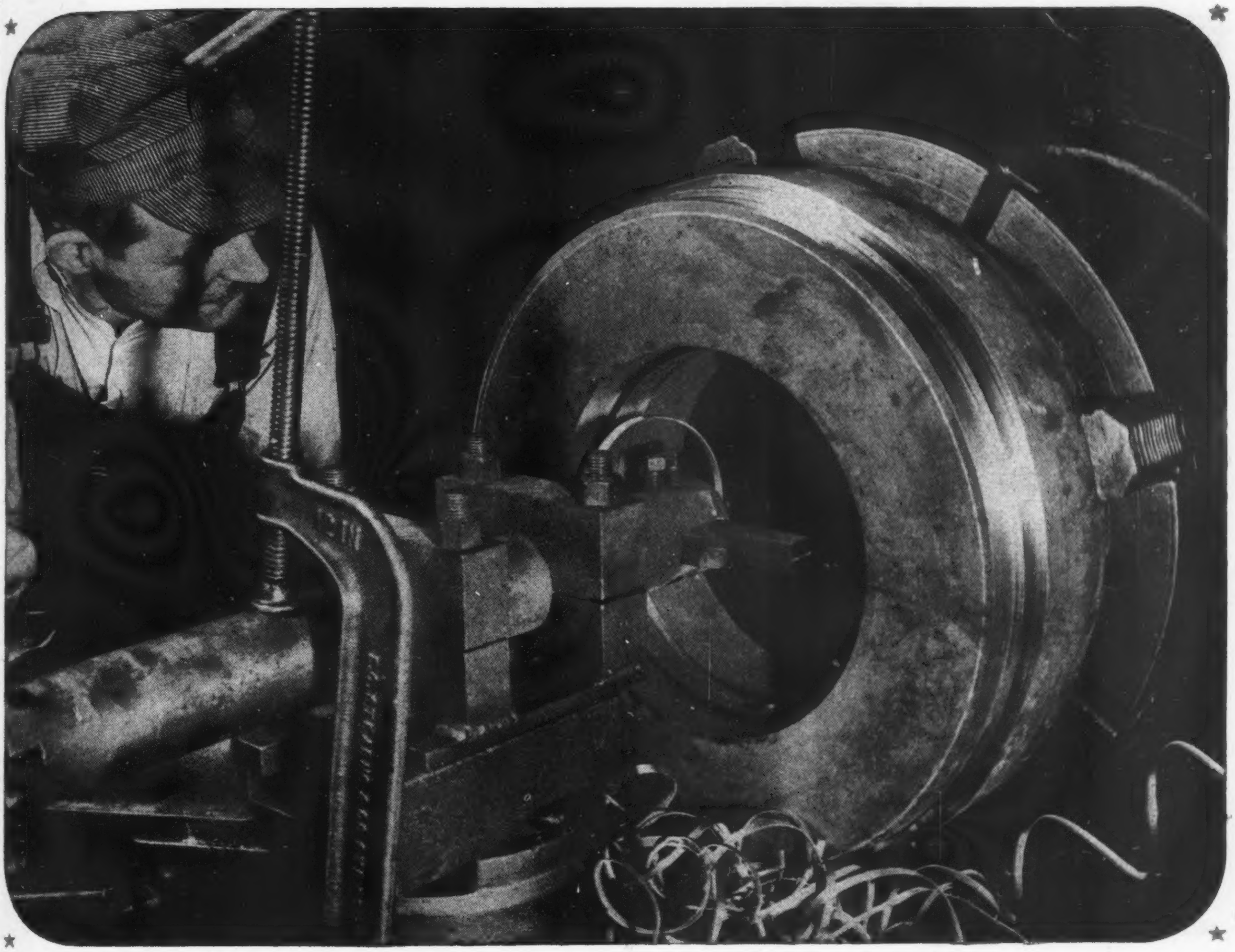


Reciprocating racks guided by tilting arms alternately engage and disengage ring gears at ends of the stroke, furnishing an intermittent drive to the turret spindles

sponding gear. The mechanism for effecting the shift at the ends of the stroke is shown in the lower left illustration and includes an air cylinder which actuates a pair of T-shaped rocking brackets provided with guide surfaces in which the racks slide. Control mechanism for this air cylinder operates in timed relation with the driving cylinder shown at the right of the plan view.

As a safety feature the left-hand clamping yoke carries a safety arm having a head adapted to move under and over a stop block attached to the base. Thus when the drive is in the position shown the safety arm moves over the block, and when tilted for the return stroke the arm moves under the block. In the event of failure to tilt fully in either direction, the stop block prevents movement which might damage the mechanism.

TANK RETRIEVER demonstrates how it operates in repairing or towing disabled land battlewagons. Winch inside this Baldwin-built machine has a capacity of 30 tons.



ASSETS to a BOOKCASE

Stress Analysis for Airplane Draftsmen

By Ernest J. Greenwood and Joseph R. Silverman, engineers, Chance Vought aircraft division, United Aircraft corporation; published by McGraw-Hill Book Co. Inc., New York; 291 pages, 5¼ by 8¼ inches, clothbound; available through MACHINE DESIGN, *$3.00 postpaid.*

No attempt is made in this book to make a stress-analysis expert of the reader. Rather, its aim is to show the way toward more competent everyday design through efficient utilization of current concepts culled from experience in the development of modern aircraft.

While the volume is unpretentious in size its content affords ample coverage of the subject, the most pertinent phases of which are dealt with in a manner at once authoritative and comprehensible. Included are chapters on: Design loads on airplanes; statics; properties of materials used in airplane design; simple tension, compression and shear; proportioning of connections; centers of gravity and moments of inertia; round tubes in torsion; hoop tension, etc.

□ □ □

Technique of Production Processes

By John Robert Connelly, associate professor of industrial engineering, Lehigh university; published by McGraw-Hill Book Co. Inc., New York; 430 pages, 6 by 9 inches, clothbound; available through MACHINE DESIGN, *$4.00 postpaid.*

Every design engineer should have a clear conception of how the parts he puts on paper are made and handled in production. Ability to evaluate properly the inherent merits and limitations of the many production processes available makes him more proficient in that the parts he designs lend themselves readily to low-cost production. In addition, he works in close collaboration with the shop man, whose problems he keenly appreciates. Unfortunately, however, lack of either time or opportunity does not permit all engineers to supplement their extensive technical training with the solid practical background gained by actual work in the shop.

For the engineer desiring to augment his knowledge of production processes, this book has much to offer. It is written in a straightforward, pithy manner which makes for easy reading and quick comprehension. Gratifyingly free of extraneous data, it covers the gamut of commercial fabrication processes, including casting, forming, material removal and joining. In addition, pertinent related phases of the subject such as material handling, product standardization, methods and job study, etc., are included. Its almost overabundant illustrations are well chosen and clearly rendered.

Injection Pump

(*Continued from Page* 176)

check valve opens when injection ends and drops the line pressure existing in the system between the check valve and nozzle to a pressure below the opening pressure of the nozzle, by discharging fuel back into the chamber above the plunger.

Although this plunger does the work of the four plungers in a conventional type injection pump, it does not operate four times as fast. After determining the best plunger velocity for injection by actual test on any particular application, results showed this velocity to be essentially the same as that of a plunger of similar size in a conventional pump operated under the same conditions.

Reference to *Fig.* 6 reveals that the simple harmonic motion obtained with an eccentric is less severe on the plunger and plunger return spring than is the cam action of a conventional pump. Proof of this is further evidenced by the fact that breakage of plunger return springs on the single-plunger pump is unknown, despite the fact that this spring does the work of four springs in a multi-plunger pump.

Uniform Fuel Delivery

To obtain uniform fuel delivery from all four nozzles at all operating speeds and fuel settings was a problem requiring considerable development. All of this work was done on a test bench with the injection pump driven by a variable-speed electric motor. Delivery through nozzles into glass graduates, with facilities for instantly switching to or from these graduates, made it possible to check uniformity of fuel delivery between nozzles at all speeds and fuel settings. From the beginning, fairly uniform delivery between nozzles was obtained through the lower speed range at all operating fuel settings. However, this was not the case at higher speeds where wide variations would occur in fuel delivery to the four nozzles. The reason for this variation was found to be the nonuniform charging of the chamber above the plunger. This condition, in turn, was caused by a pressure wave set up by the back surge of fuel from the injection line when the plunger uncovered the port at the end of injection.

Pressures in the chamber above the plunger during injection range between 2000 and 4000 pounds per square inch depending on operating conditions. When port opening occurred, the primary fuel supply system, carrying a pressure of approximately 35 pounds per square inch was suddenly subjected to the high pressure existing above the plunger. This disturbed the charging through the higher speed range to such an extent that it was possible to start with uniform delivery between nozzles and, by gradually increasing the pump speed, two nozzles (every other one) would deliver more and more fuel per stroke, while the other two would deliver less and less, until all the fuel was delivered by two nozzles. A synthetic-rubber diaphragm installed on the supply pump side in the plunger unit assembly entirely corrected the trouble and uniform delivery was obtained from all four nozzles throughout the speed and fuel delivery range. However, because of the questionable durability of syn-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IF YOU ARE FACED with a Fractional H.P. Motor problem involving large quantity production, why not turn to the FASCO organization whose vast facilities are at your disposal to develop, tool and produce that motor for you? . . . custom-built of course to your specifications! A letter will bring you complete information. Write today!
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Shown above are three of the many Pilot Fractional H.P. Motors available to industry. (Left to right) Geared Head Types, A.C. or D.C. from 1/1000 to 1/4 H.P. Universal Types, A.C.-D.C. from 1/500 to 1/4 H.P. (custom-built to specifications) and Pilot Blowers standard and custom-built types to deliver from 12 to 200 C.F.M.
BACK THE ATTACK! BUY MORE BONDS!
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MOTORS

thetics at that time, plus the need for by-passing a certain amount of fuel to vent the injection system and to lubricate the scavenging pump, a by-pass valve and spring were used which served the same purpose.

Reverse Check Valve

Another important problem was the elimination of exhaust smoke. High-speed motion pictures of combustion in the precup showed that the trouble was caused by fuel dribbling from the nozzle after injection ended. This had been previously indicated by oscillograms of the pressure phenomena in the high-pressure system and by similar studies made with a cathode-ray oscillograph and piezo-electric crystal. Since injection line pressures range between 2000 and 4000 pounds per square inch and the nozzles are set to open at 700 pounds per square inch, the high pressure, which existed in this line after the opening of the port and closing of the check valve, caused the nozzle to dribble until line pressure and nozzle-opening pressure were equalized. Dribbling was corrected by the introduction of the reverse-check valve to relieve the pressure in this line. Various types of masked or displacer valves were tried instead of the check valve above the plunger, but exhaustive tests, covering a wide range of speeds and fuel deliveries, showed a distinct advantage in dropping the line pressure to a constant predetermined level by using a reverse-check valve. The instant injection ends, the reverse-check valve drops this pressure to approximately 600 pounds per square inch (100 pounds per square inch lower than the opening pressure of the nozzle), thus preventing any troublesome dribbling.

Another requirement was a satisfactory check valve in the return fuel system. The scavenging pump was originally designed to return only the fuel that leaked past the distributor valves and plunger. However, this leakage was such a small amount that it did not adequately lubricate the scavenging pump. A method of lubricating the pump was provided by the necessity of using a by-pass valve in the metering assembly to obtain proper charging of the chamber above the plunger. The problem then was to work out a check valve that would prevent fuel from backing up through the return fuel system and flooding the pump sump when the engine was not in operation and which would open when the pump was in operation to permit return of leakage fuel to the supply tank.

In the final construction, shown in *Fig.* 4, a lapped piston and barrel were installed in the leakage passage. This piston, or scavenging valve, is opened by primary pump pressure when the pump is in operation and is closed by a spring whenever operation stops.

Governor and Torque Control

Probably the most difficult problem of all was to develop a satisfactory overload speed control, which we call a torque control. To work out a flyball governor to give the right amount of control-rack motion and to give acceptable speed control from full load to no load was relatively simple. The conventional type of flyball governor was used, in which the governor energy, bal-

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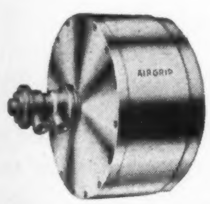
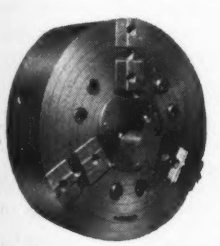


"Airgrip" high speed revolving air cylinder.



"Airgrip" air operated universal Three-Jaw Chuck.

Equip your machines to increase production by more than 25%. You will make a larger contribution to the war effort and attain lower cost per unit. You will have machines that can produce at maximum capacity—machines that will be ready for the fastest possible change-over to peacetime products—machines that will meet reconversion in low production cost, maximum output, and highest quality.

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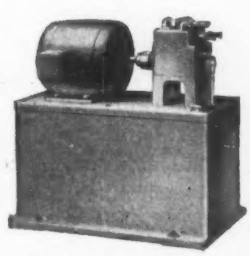

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anced by springs, is transferred to the plunger by means of a governor sleeve, fork and rack. The governor fork, mounted on a cross-shaft is held against the governor sleeve by the governor springs and is attached to the rack, which rotates the plunger whenever the governor weights move together or apart. However, to work out a torque control which would give the required increase in torque with a decrease in speed for satisfactory overload lugging characteristics, was not a simple matter. In general, the overload performance calls for a gradual increase in torque with a decrease in speed until at peak torque the engine is pulling 12 to 14 per cent more torque than at full load, at a speed of from 40 to 50 per cent that of the full-load governed speed.

Automatic Control Needed

Throughout the speed range, fuel delivery characteristics of the pump, in terms of fuel per stroke for any fixed governor setting, are approximately constant. So it becomes obvious that to increase the torque of an engine with a decrease in engine speed requires some automatic control which properly increases fuel delivery per stroke with a decrease in engine speed until maximum torque is reached. The torque control, in addition to governing the engine from full-load to peak torque, had to be simple, reliable and durable. It was also important that it be confined within the pump and be flexible from an adjustment standpoint to meet special engine requirements, as well as variations found in the general run of production engines and injection pumps.

Our first problem, of course, was to work out a torque control regardless of size or kind that would automatically give the required engine performance between full-load and peak torque. Many methods were tried, among them magnetic and hydraulic torque controls. However, it became apparent that as long as we used a flyball governor for part load control, the most satisfactory plan would be to use this same governor for overload control. An analysis of this problem from a governor standpoint showed that to do this with a flyball governor would require a mechanism in which the spring force would always be in balance with the energy of the governor weights throughout the speed range from full-load speed to peak torque, and also that the governor weights would move together or apart the right amount to increase or decrease fuel delivery per stroke to the engine with each change in speed. Since the energy of a flyball governor varies as the square of the speed and, since the engine speed at peak torque is from 40 to 50 per cent of full-load speed, the governor energy at peak torque would be one-fourth, or less, of that required at full load.

Specifically, this device, in governing between full-load and peak torque speeds would have to move the governor weights together or apart the right amount to increase or decrease fuel delivery per stroke for each change in speed. In order to do this it would have to increase or decrease the spring force which balances the force of the governor weights; first, to meet their rapidly changing power which follows each change in speed and, second, to meet their change in power due to moving together or apart. To those uninitiated in the mysteries and vagaries of flyball governors, this may seem a simple

problem, but much thought and effort were required before a torque control was developed which fulfilled all requirements. The complete governing problem for both part load and overload was finally solved by making use of two sets of springs; one set of regular governor springs to control engine revolutions per minute from governed speed full load to high idle no load (and slow idle), and another set of torque springs to govern between full-load and peak torque speeds.

As finally developed, the torque control (*Fig.* 7) made use of a set of flat leaf springs and a specially shaped seat. The principle upon which it works is simple. As the torque springs are pressed tighter against their seat their effective length decreases and consequently their rate increases. In this manner it was possible to vary the torque spring rate and thus balance the rapidly changing governor energy as the speed changed between full-load and peak torque speeds and, at the same time, move the governor weights the right amount to vary fuel delivery per stroke to meet engine requirements.

How Torque Springs Function

Torque springs and seat are installed in a torque arm which is mounted and free to oscillate within limits on the governor fork shaft. The regular governor springs are attached to this torque arm. Energy from the governor weights is transferred to the torque springs in the torque arm through a torque lever keyed to the governor fork shaft. Since the torque arm can oscillate within limits on the governor fork shaft the torque lever can oscillate in the torque arm within these same limits. At full-load governed speed the governor springs hold the torque arm lightly against a stop, and the torque springs are compressed a maximum by the torque lever, which is also resting lightly against a stop in the torque arm. If the engine speed increases, the energy of the governor increases and pulls the torque arm away from its stop, and so the torque lever (already against its stop in the torque arm) and the torque arm act as a single lever. Thus the torque springs, although compressed to a maximum, are not in action whenever the engine is operating between full load and no load. Likewise when the engine is operating between full-load and peak torque the governor springs are not in action but the torque springs are. The reason for this is that at full load the torque arm is held lightly against a stop and any decrease in speed does not permit change in governor springs except to hold the torque arm tighter against this stop. However, since the torque springs compressed by the torque lever are balancing the governor energy at full-load speed, when the engine speed drops, causing the governor to lose energy, the torque springs move the torque lever back until torque spring force and governor force balance one another. This increases fuel delivery per stroke to the engine and is possible because the torque lever is free to oscillate within the torque arm. Any further decrease in speed causes additional backward movement of the torque lever and a further increase in fuel delivery until peak torque is reached, at which point the torque lever strikes a stop and no further increase in fuel is possible. With an increase in speed, of course, the reverse takes place until full-load speed is reached.


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Engineering a System for "Engineering"

(*Concluded from Page* 139)

The flow chart, *Fig.* 3, arranges the successive steps chronologically in vertical columns reading from left to right, and the order in which the drawings and associated forms are prepared is also indicated in their relative stages of creation by reading from top to bottom. Captions heading each vertical column show successive stages of productive work, and checking by supervision before additional data are prepared and accumulated in a subsequent productive stage which is largely dependent on basic information accumulated previously. While it is not intended to thrust additional and detailed duties of minute checking upon those acting in a supervisory capacity, flagrant errors can be detected readily by a cursory examination of the work and a closer control from section to section is possible. At the same time the simplification of work in each step to two or not more than three specific duties for the worker makes it possible to provide adequate instructions and give the necessary assistance to untrained personnel.

Fitting the Job to the Worker

An attempt has been made to integrate and delegate the work on a basis consistent with the experience and training of the worker. Although designers should not be burdened with clerical details, in our organization it is advantageous to have the parts in a unit listed on a bill of material in their proper relationship as principal and component parts by the designer because of his familiarity with the unit. For the same reason no one is better qualified to know the reasons for, or extent of, part alterations in an engineering change than the designer. The information which he notes on a handwritten change notice form can subsequently be transcribed by a typist and forwarded to interested departments. Preparation of the part card envelope and component parts list for use by the cost department, finished parts stores office and stock room clerk can be handled by clerical employes just prior to typing the bill of material.

The system established is confined to the engineering department but the needs of the plant departments also were studied with the idea of planning the program and routine within the engineering department so that the information which they require to perform their respective functions can be automatically provided.

The chart shown in *Fig.* 4 begins with the distribution of the information required by each of the associated departments, and represents by symbols and descriptive comments the functions performed by each during the course of a production cycle.

This chart illustrates how the system recognizes the interdependence of all departments and provides the necessary information in such a way that their own routines are not radically changed in utilizing the data received from the engineering department.

In a few words, the proper engineering information arrives at the proper place at the proper time.

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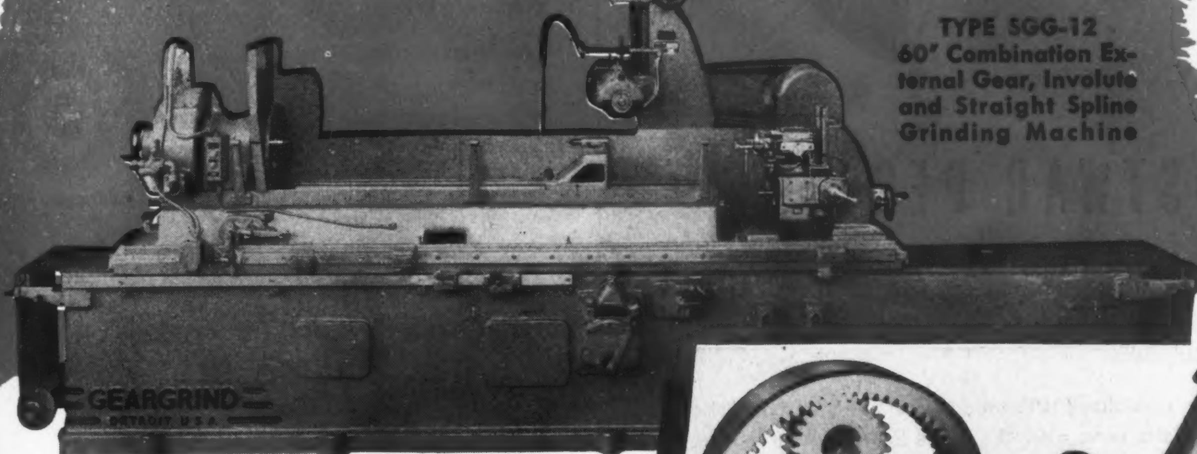

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Surface Fatigue

(*Continued from Page* 170)

sults may be applied safely to design. Results of these tests, which were started in 1931, have been successfully applied in the design of cams and their roller followers and in the design of gears. The comparative results between different materials as found in these tests are confirmed by the behavior of these materials in service as elements of automatic machines operating in production. The limiting loads, as determined from these tests, have thus far resulted in designs with no appreciable wear.

For the purpose of setting up a load-diameter-stress factor, a good procedure is to start from the Hertz equation for the stresses set up between two loaded cylinders in contact. When

s = maximum specific compressive stress, pounds per square inch

w = load on cylinders, pounds per inch of length

r_1 and r_2 = radii of cylinders, inches

E_1 and E_2 = modulus of elasticity of materials, pounds per square inch

$$s^2 = \frac{.35w(1/r_1+1/r_2)}{(1/E_1+1/E_2)}$$

Now introduce an experimental factor of load and stress concentration, based on the test values. Then K_1 = experimental load-stress factor for two cylinders, or

$$K_1 = w(1/r_1+1/r_2) \quad \text{(by definition)}$$

and

$$w = K_1/(1/r_1+1/r_2)$$

Referring now to Table II which gives the test results on a semisteel roll of 4 inches diameter running with a hardened-steel roll of 2.3 inches diameter, both with a face width of 1-inch, the experimental surface-endurance-limit load is 1600 pounds. This gives the following values for use in the foregoing equation:

$$w = 1600 \text{ pounds}$$

$$r_1 = 1.15 \text{ inches}$$

$$r_2 = 2 \text{ inches}$$

$$K_1 = 1600(1/1.15+1/2) = 2191$$

These factors (K_1) are used to determine the limiting surface loads between two curved surfaces. The limiting loads are the ones which can be carried indefinitely without appreciable wear. (If abrasive particles are present, these values do not apply.) For example, if the minimum radius of cam curvature is 4 inches and the cam roll is 2 inches in diameter, the cam being made of semisteel and the roll of hardened steel, then

$$r_1 = 1, \quad r_2 = 4$$

$$w = 2191(1/1+1/4) = 1.25 \times 2191 = 2738 \text{ pounds}$$

For involute-spur-gear teeth, where

K = Load-stress factor for gear teeth
ϕ = Pressure angle
D_1 = Pitch diameter of pinion, inches
D_2 = Pitch diameter of gear, inches
N_1 = Number of teeth in pinion
N_2 = Number of teeth in gear
F = Face width of gears, inches
W_w = Limiting load for wear, pounds
Q = Ratio factor

$$r_1 = D_1 \sin \phi/2$$

$$r_2 = D_2 \sin \phi/2$$

$$(1/r_1+1/r_2) = (2/\sin\phi)\,(1/D_1+1/D_2)$$

Let

$$K = s^2 \sin\phi (1/E_1+1/E_2)/(4\times.35)$$

$$Q = 2N_2/(N_1+N_2) = 2D_2/(D_1+D_2)$$

$$W_w = D_1 F K Q$$

The value of (K_1) for cylinders is

$$K_1 = w(1/r_1+1/r_2) = s^2(1/E_1+1/E_2)/.35$$

$$K/K_1 = \sin\phi/4$$

$$K = K_1 \sin\phi/4$$

TABLE IV

Load Stress Factors

Material	Cylinder K	Gears 14½ deg K	Gears 20 deg K
Semisteel	2191	137	187
Nickel cast iron	1369	85	117
Nickel iron, heat-treated to 300B	1643	102	140
Nickel iron, heat-treated 350-400B	1917	120	163
Nickel iron, interrupted quench	3286	205	280
Nickel iron, interrupted quench, with 9 per cent sliding	2465	154	210
Chrome-nickel cast iron	1506	94	128
Molybdenum cast iron	1917	120	163
Molybdenum iron, interrupted quench	3697	231	316
Phosphor bronze, sand cast	1177	73	100
Phosphor bronze, chilled	2054	128	175
Phosphor bronze, sand cast and nickel iron, interrupted quench	2739	171	234

Hence, for this combination of semisteel and hardened steel, the following applies:
For 14½-degree gears

$$K = (2191\times.25038)/4 = 137$$

For 20-degree gears

$$K = (2191\times.34202)/4 = 187$$

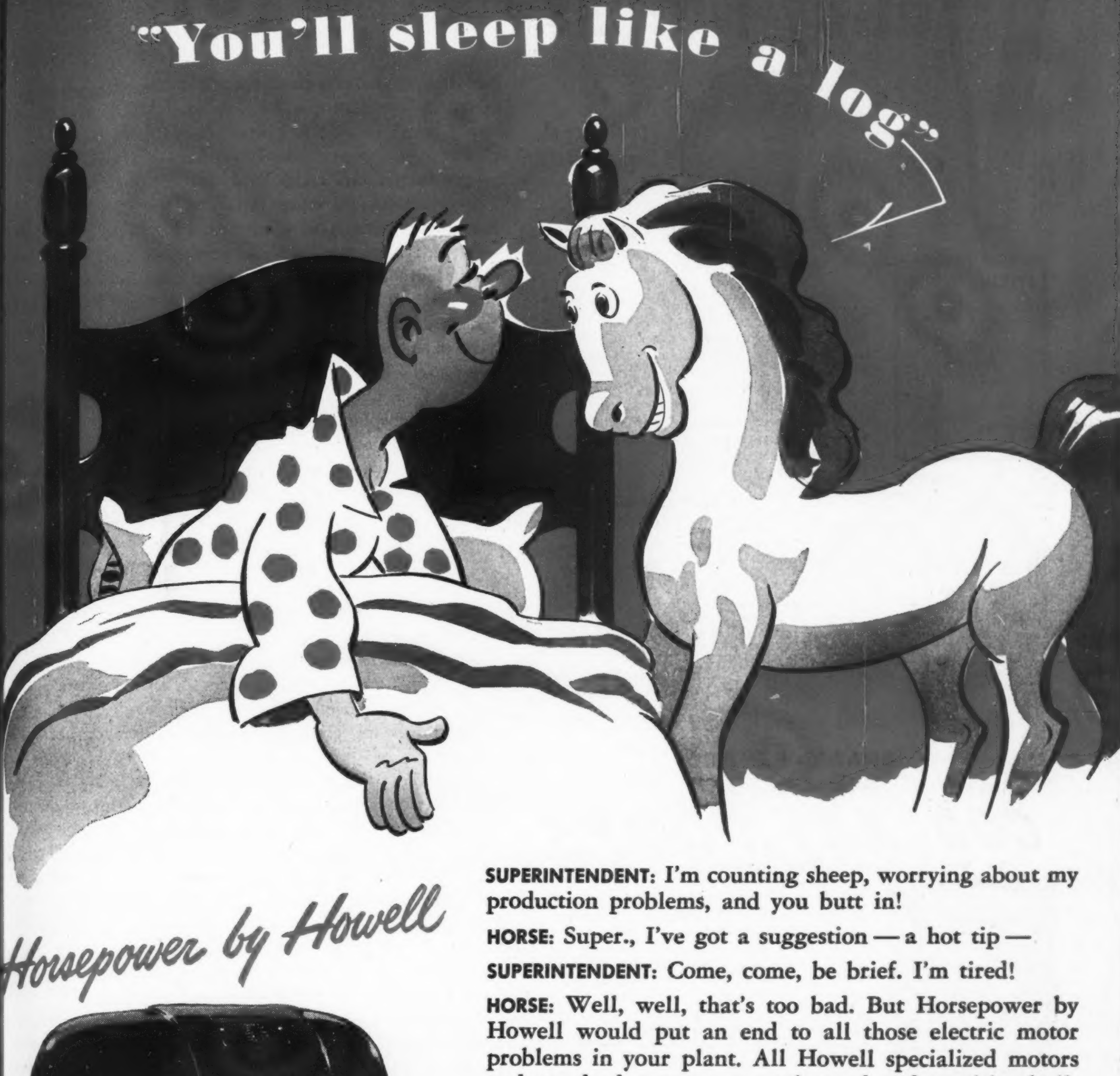
For example, using a pair of 6 DP gears, 20-degree pressure angle, 2-inch face, of 24 and 36 teeth, the following values for the limiting wear-load equation are given:

$$N_1=24 \quad N_2=36 \quad D_1=4 \quad K=187 \quad F=2$$

$$Q=72/60=1.2$$

$$W_w = 4\times2\times187\times1.2 = 1795 \text{ pounds}$$

The values of (K_1) and (K) given in TABLE IV have been computed in this manner from the experimental values. Except where noted otherwise, a hardened-steel test roll has been used in contact with the material specified.



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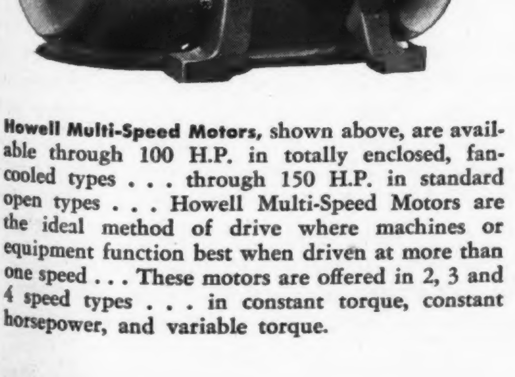

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HORSE: You bet you can! Folks quit worrying when they buy Howell Motors. They know they have a precision-built, properly insulated, quieter operating motor. With Horsepower by Howell in your plant, you'll sleep like a log.

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HOWELL ELECTRIC MOTORS COMPANY

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Choosing the Right Material

(*Continued from Page* 157)

the desired life, the fundamental information given by creep tests seldom can be dispensed with. The plural "creep tests" is used in this statement, because a family of creep (i.e. time-deformation) curves is necessary for proper insight into creep behavior, *Fig.* 20.

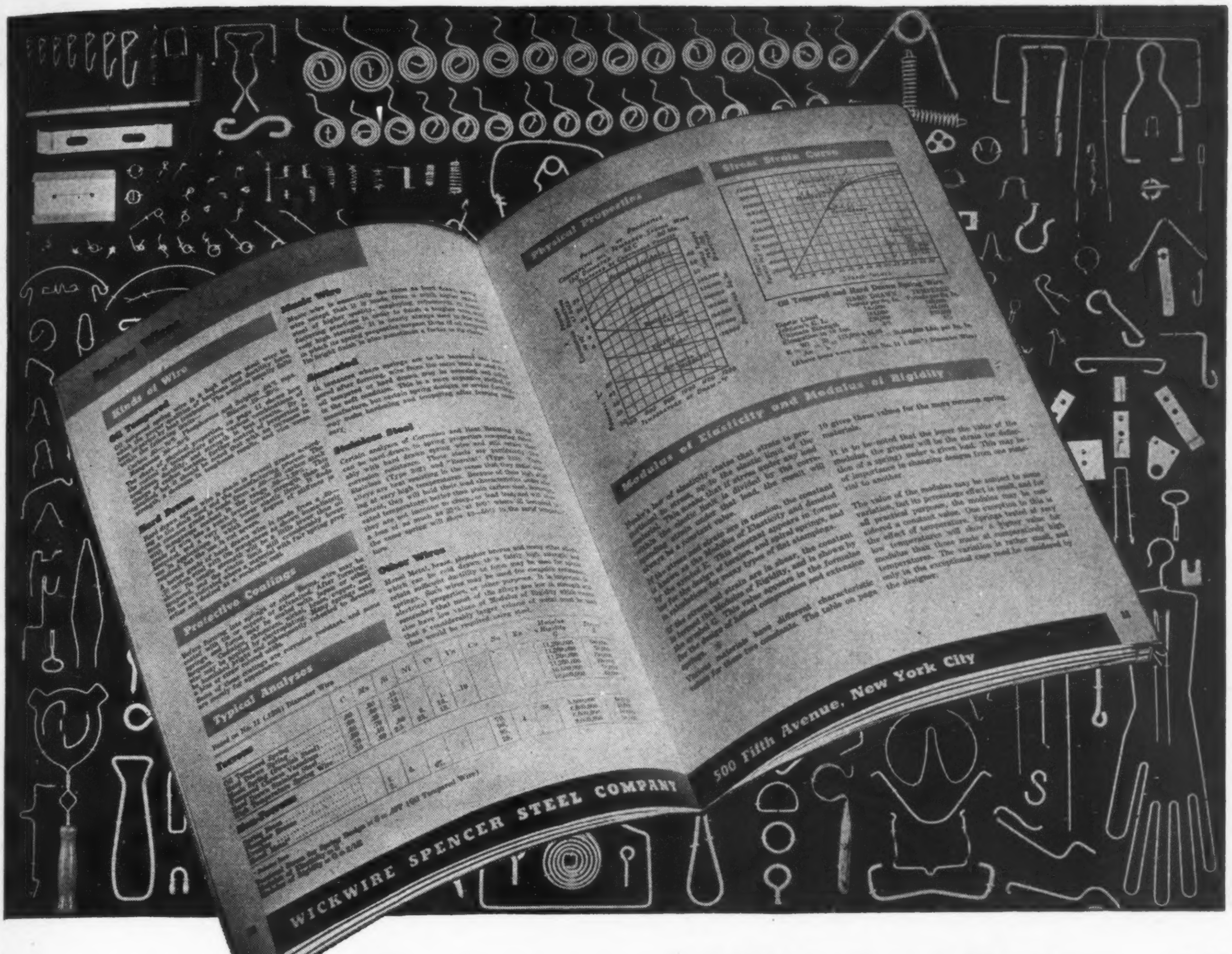
Interpretation of creep data involves extrapolation at best, for, in some types of service, a life of 100,000 hours or more, is demanded without exceeding some very small amount of deformation. Yet, on the basis of one set of creep tests that were actually continued for 100,000 and another set for 20,000 hours, behavior is shown that could have been anticipated from a family of creep tests with those at the lowest stresses carried to around 2000 hours, but not from a single test. Even 2000-hour tests are too long for acceptance testing, and much futile effort has been spent in attempting to devise an "accelerated" test. Short-time, high-temperature, yield-strength tests reveal nothing accurate about creep behavior and serve only to eliminate materials not worthy of creep testing.

Some of the more highly alloyed heat-resisting alloys, originally nonmagnetic at room temperature, are unstable in another way. They may throw out a brittle magnetic constituent in a certain temperature range, and the chemical composition has to be balanced so as to avoid this, which limits the opportunities for replacements of some of the alloying elements by others. There is a wider possibility of replacement when the alloys are used at lower temperatures for corrosion resistance, not for heat resistance.

From the point of view of service one may need information on resistance to a particular corrosive atmosphere, on the creep at a given temperature, on the effect of fluctuating temperature, and on whether the alloy is unstable at any range of temperature the part must pass through in service. Sometimes the sum total is best found by devising a special simulated service test in which all the conditions to be combatted are present. More often it is better to apply more standardized tests that have been worked out so that known ways to get precision can be applied that would be difficult to apply in a simulated service setup, and to draw conclusions on the sum total of these tests. At least, the individual tests should be applied first, when exploring new alloys, to cut down the number to which the simulated service test need be applied.

Many Alloys Are Aging Type

Many of the alloys which show useful high temperature load-carrying ability appear to be of the precipitation-aging type. Under the influence of temperature and stress, submicroscopic or finely divided material—previously in or put into solid solution by a suitable heat treatment—comes out of solution in a fine dispersion, thereby strengthening the matrix. If the stress, temperature and time are insufficient, these particles may grow or agglomerate until they are too large and too sparsely distributed; their strengthening effect then is lost or materially de-



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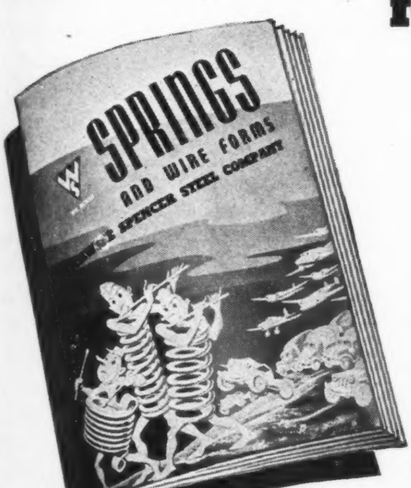

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creased. Such propensities are too marked for even the casual observer to overlook in the behavior of lead alloys at very slightly elevated temperature and, at some sufficiently elevated temperature, most steels and other alloys get soft enough to be comparable in behavior with lead.

Important changes in dimensions sometimes occur with time or in service when an alloy is not perfectly stable in its original condition. Aluminum alloy pistons are given a stabilizing heat treatment so they will not increase in volume during service and seize. Steel gages are specially stabilized. Internal stresses, produced by cold work in forming an article, in machining it, or in welding under constraint, may have to be relieved by suitable heat treatment.

Other slowly occurring metallurgical changes take place in some useful alloys. Iron-containing alloys that are capable of existing in magnetic and nonmagnetic forms, according to composition and temperature, may be sluggish in getting into their really stable form when border-line compositions and temperatures are involved. For reasons of economy or conservation and to use the alloys at the maximum temperature they will stand, border-line compositions and temperatures are often involved. Such alloys may remain nonmagnetic in brief service, or in a short test, yet in a longer period may separate out a stable, magnetic constituent of poor mechanical properties with a deteriorating effect on the alloy as a whole. Some types tend to separate out nonmagnetic, but brittle, compounds, so the absence of magnetic change is not conclusive.

Ductility During Brief Overloads

One type of test that gives useful information about what to avoid, but which has given some designers unnecessary jitters, is the "stress-rupture" or "load-to-fracture" test in which excessive loading is continued till the specimen actually breaks. Just as short-time tensile strength is not the true criterion for ordinary design in which yield strength is the important thing, so the stress-rupture data are only of limited use in design. For a while it was hoped that by logarithmic plotting, stress-rupture data could be extrapolated to indicate creep resistance. This was illogical, because no one would expect an assembly of tensile data, devoid of yield data, to give correct information about yield strength. There are some special uses, such as in aircraft engine superchargers, in which the engineer is satisfied to abuse his material, consider it expendable, discard it and send it back for remelting after, say 1000 hours service. If these cases are such that a large amount of distortion is permissible, stress-rupture tests extending to 1000 or 2000 hours are logical for testing the behavior of the material. Even in these cases in which a relatively short service life and appreciable deformation is anticipated in the design, actual failure cannot be tolerated and the trend is toward obtaining in these high-stress stress-rupture tests not only the time for fracture and the ductility but also the time-deformation characteristics so that the design engineer is given information as to the rates of deformation and times required to produce usable deformations at the stresses of interest.

Stress-rupture tests serve to give the metallurgist added


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information on stability and the ductility to be expected during brief periods of overload of materials more conservatively stressed. However, they can do much harm in steering the designer away from perfectly usable materials if he takes their results, obtained under conditions not relevant to his usage, to imply behavior under his usage.

Effects of Fluctuating Temperatures

A factor in metallurgical stability that has had too little attention so far is that of fluctuating rather than constant temperature. Few articles used at high temperature do not have to withstand cooling and heating cycles repeatedly through their life, sometimes under stress. That is no argument against constant temperature tests; they are essential for base-line information, but they may need to be supplemented by tests under controlled fluctuations of temperature.

Just as in ordinary corrosion, the type of corrosion or oxidation product formed controls the progress of the attack whereas adherent, tough and impervious films tend to decelerate or stop attack, while flaky or spongy films may accelerate it. The effect of the scaling behavior of heating and cooling, and of changes in the gases bathing the specimen, can be studied as by a merry-go-round outfit shown in *Figs.* 21 and 22.

New Alloys Will Outdate Present Ones

Scarcity of alloying elements makes it necessary to sail closer to the wind and to hunt for new alloys of the necessary properties that require less of the strategic metals. Concurrently, new war requirements demand alloys of hitherto unattained properties for uses so important that the sky is the limit in the degree of alloying or choice of alloying element, since the necessary amount would be pinched off from something else of less military importance. Consequently the whole art of high temperature alloys is in a state of flux, with many promising leads not yet sufficiently explored to allow definite statements and some definite achievements not stateable because of war censorship. Discussion of the older alloys, a discussion destined soon to be considerably out-dated, is all that can be given at the present moment.

One high temperature use is in bolting stock, as for use in high-temperature high-pressure steam connections where bolts are drawn up to a considerable elastic extension, which stress it is desired to hold so as to keep the joint tight. The temperatures involved are relatively low, the stresses relatively high—high enough to demand heat-treated steels. Whatever plastic flow occurs lowers the stress from its initial value. Testing as in a creep test, at constant stress, does not reproduce service conditions, so "relaxation test" methods are used instead.

Bolting steels, for bolts of large cross section for service at 750-1100 degrees Fahr., are chosen from a large group of fairly high carbon, deep-hardening steels, usually with 1-1¼ per cent chromium or containing generous qualities of molybdenum or tungsten, molybdenum being the usual choice. This addition is made for several reasons. Molybdenum notably confers creep resistance, especially upon

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ordinary heat-treatable steels; it prevents or greatly minimizes temper brittleness on slow cooling after tempering, or loss of impact resistance on sojourn at elevated temperature; it introduces resistance to tempering; and it increases depth hardening. Tungsten has somewhat similar influences but about twice as high a percentage of tungsten as of molybdenum is needed. Mixtures of both may be preferable to either alone.

The heat treatment is generally by oil quenching or normalizing, followed by tempering at at least 200 degrees Fahr. above the operating temperature. ASTM specification A-193-37T lists so large a number of compositions as to make it clear that the mechanical properties and stability desired may be obtained by a variety of compositions, including others beside those listed.

Molybdenum Aids Creep Resistance

Piping and tube for elevated temperature service are generally given the desired creep resistance by introduction of around ½ per cent or more molybdenum (around 1 per cent tungsten is sometimes substituted). If corrosion resistance is needed as well as strength, to the carbon-molybdenum base there is added chromium, as little as 1 per cent being effective against some corrosive conditions, 5 per cent being largely used—especially in the petroleum industry— and all graduations below that content and above it, up to around 15 per cent, being employed to suit particular conditions.

Such steels, for these uses, are annealed or normalized and then drawn some 200 degrees Fahr. above the operating temperature. They are of much lower carbon than the bolting steels. Modifications in the corrosion resistance and oxidation resistance may be made by introduction of silicon or aluminum or both in addition to chromium. ASTM specification A158-37T and trade publications of the Babcock and Wilcox Co., the Timken Roller Bearing Co., the Steel and Tube Division of The National Tube Co., and other producers, deal with those steels. Intergranular corrosion and cracking, low ductility in stress-rupture tests, and their avoidance, in this family of steels have occasioned much metallurgical discussion, while engineering evidence of long continued service at reasonable loads and temperatures without failure, and the prevalence of ductile failure rather than brittle failure when the steels are mistreated in service by being carried to temperatures far above those contemplated in design, indicate that the pessimism of some metallurgists about the behavior of this group of steels when mistreated needs to be tempered by the optimism of the engineer who has not mistreated them.

Heat Treatment To Furnish Ductility

In spite of the work done upon such steels, Wilson[9] suggests that properly balanced alloy contents lower than those often advocated might accomplish nearly all that is claimed for more highly alloyed compositions and serve the cause of conservation. The metallurgy of such steels has not been fully settled, in spite of the existence of specifications, for the group is a tailor-made one in which

[9] Wilson, R. L.—Discussion Page 1301, *Transactions* A.S.M., Dec., 1942.

the composition and the heat treatment for stability have been varied considerably in the effort to meet special conditions in the most economical fashion, as well as to provide a reassuring degree of ductility under abuse. Miller and Smith[10] point out that a heat treatment assuring a high degree of stabilization can be applied to secure the ductility more commonly sought by alloying.

In the plain carbon, carbon-molybdenum, and more complex low alloy steels for high temperature service, it is noteworthy that, at the higher range of temperature for which a given member of the group will serve, coarse-grained structures show better creep resistance than fine-grained ones, though in some cases there is evidence that coarse grain accompanies rather than causes the fundamental condition that makes for better creep resistance.

Finishing Methods Affect Creep

The mode of finishing the heat of steel certainly has an influence, for rimmed steels are recognized as inferior in creep resistance to killed steels, even when both are made coarse grained. As in killed steels, rimmed steels can be notably improved in creep by addition of molybdenum.

Up to around 1000-1100 degrees Fahr., respectable load-carrying ability, plus a tailored degree of oxidation and corrosion resistance, can be built into ordinary and only relatively slightly alloyed steels, but for high load carrying ability at more elevated temperatures, recourse must be had to the "austenitic" types, the steels that do not harden on quenching and are not amenable to the usual sort of heat treatment. They may respond to precipitation-hardening treatment, so the composition is balanced and solution and aging heat treatments chosen so that advantages rather than disadvantages result from the particular precipitation phenomena involved.

Chromium Produces Protective Scale

The least highly alloyed austenitic steels in common use have composition approaching 18-8 stainless. Creep strength of this at 1100 degrees Fahr. is two or more times as high as that of the ordinary low alloy steels, and it still has some load-carrying ability at 1400 degrees and a bit above. For use in the intermediate temperature range from 1200 to 1600 degrees Fahr., chromium-nickel-iron, cobalt and nickel base alloys with suitable additions of molybdenum, tungsten, columbium, titanium, tantalum, and nitrogen show usable load-carrying ability. For load-carrying ability at 1800 degrees and above, still more highly alloyed compositions, such as 24 percent chromium and 12 percent nickel, or 16 percent chromium and 25 percent nickel plus several percent of molybdenum, tungsten, or columbium, or a combination of these are required. Some of the nickel may be replaced by manganese, though not much is known about what this replacement does to load-carrying ability.

The primary reason for the high alloy content is that, as the temperature increases, more and more chromium is needed to produce a tightly-adhering, protective scale, and that, as the chromium is raised for this reason, the

[10] Miller, R. F. and G. V. Smith—Discussion, Page 1300, *Transactions* A.S.M., Dec., 1942.

nickel or some substitute for it has to be increased to preserve the austenitic structure that leads to load-carrying ability. Other elements—carbon in particular, nitrogen, silicon, manganese, molybdenum, tungsten, titanium, and columbium—all play a part in shoving the structure toward or away from the austenitic stage, in affecting ease of casting and fabrication, propensity towards precipitation phenomena, etc. If some of them get too high, a weak and brittle nonaustenitic structure is produced at some range of temperature.

Compromises Caused By Fabrication

Wrought alloys are more readily produced with low carbon content than cast alloys and some of the complications are reduced when the carbon is low. The stronger, more highly alloyed compositions are not easy to roll or forge and compromises have to be resorted to when fabrication by hot or cold working is necessary. In these, as in all castings, it should be emphasized that a design that allows adequate feeding and careful foundry practice is far more important than the particular composition used.

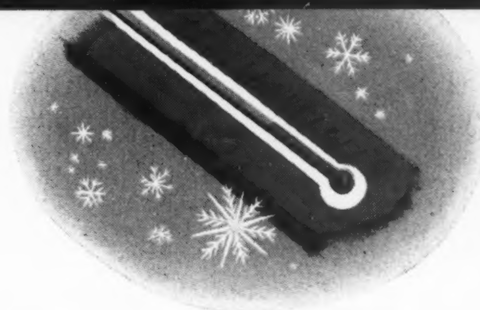
Still more highly alloyed compositions than 25 chromium and 12 nickel, are used for heat-resistant purposes, one of these approximating 15 chromium-35 nickel, being often considered superior to 25-12 for extremely severe service, though evidence on this score is not convincing save in a few special cases. The War Production Board has urged that users of 15-35 shift to 25-12, and those of 25-12 to 18-8, and this has been successfully done in many instances.

In general, when a marked change is made in composition, such as substitution of manganese for much of the nickel, of silicon for some of the chromium, or addition of molybdenum to better the load-carrying ability, some properties or the stability in certain temperature ranges are adversely affected. A new balancing and a compromise in properties are required.

Engineering Balances Alloy Properties

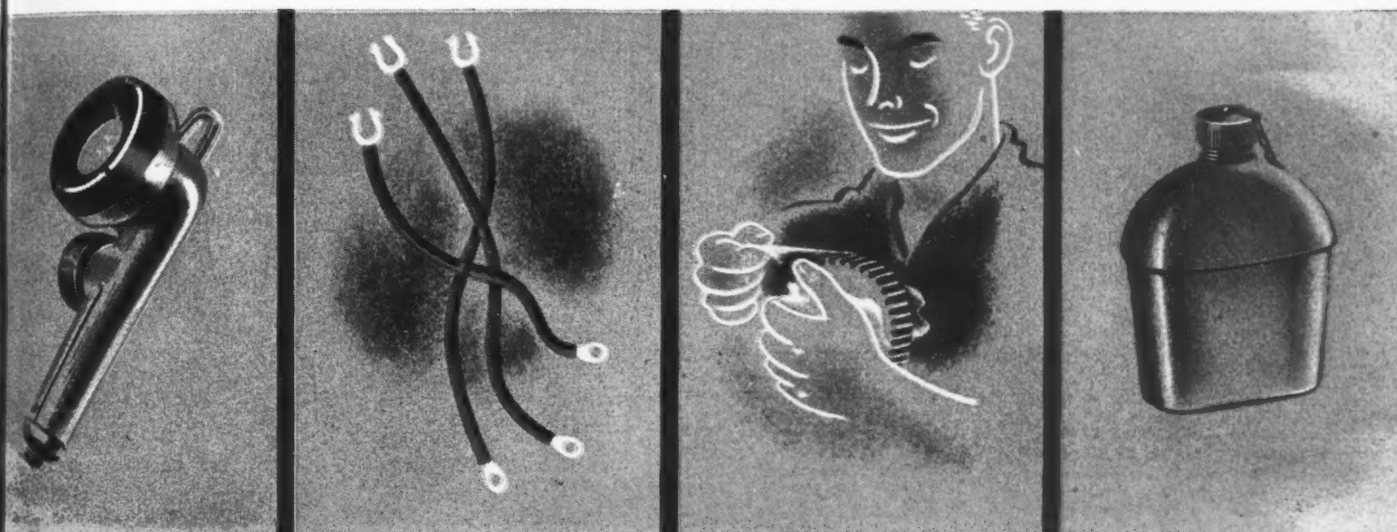
One service in which an abundance of requirements has to be met is in aircraft engine exhaust valves. Resistance to deformation at high temperatures, resistance to oxidation, resistance to corrosion by the decomposition products of tetraethyl lead, resistance to wear both on the seat and on the guide, ease of fabrication, and ability for heat transfer have to be present in the alloy or be engineered into the valve in one way or another.

For severe duty, rather highly alloyed austenitic steels are employed, with special additions to produce a balanced compromise in properties. Not all the features needed can be supplied in one alloy; the others must be engineered in, as by using a Stellite facing on the valve seat to resist wear and employing a hollow stem enclosing sodium for purpose of heat transfer. Still further engineering, especially for increasing ease of fabrication, is under way. The testing of an exhaust valve alloy involves getting the answers to questions as to how far one can go in meeting so many different, more or less incompatible, engineering desires as to make it an excellent example of the fact that you can't look up a few properties in a handbook and draw a specification.



All different—all tough jobs but Ethocel is the plastic specified

Ethocel is basically tough—this outstanding quality, plus wide adaptability, extends its usefulness to many different applications.



Here are four products that tell a story of diversified service. Each presents its special set of problems—yet each is best produced with Ethocel. Look them over, they may tell you how this versatile plastic can help meet your own requirements.

MOBILE MICROPHONE—Handle and housing are molded from Ethocel. Supplies high impact strength in sub-zero temperatures which protects the instrument from damage if dropped. Ethocel, in addition, is warm and pleasant to the touch and is dimensionally and electrically stable.

HIGH TENSION CABLE COATING—Ethocel has good insulation properties—resists corona cutting. Its stability to heat, light and weather improves cable coating lacquers. Its low temperature flexibility is of utmost importance in many cable applications.

STRIPCOAT INGREDIENT—Used in a new hot melt dip to protect metal parts, Ethocel supplies the essential toughness and water resistance. Its wide compatibility makes it extremely valuable in this and countless other formulations.

PLASTIC CANTEEN—This difficult job called for a plastic that could "take it." Tough handling and long service were problems that Ethocel met—contributing, in addition, lightness, good thermal insulation and ease of fabrication for mass production.

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- **STYRON** . . for fabricators producing moldings, extrusions, rod, sheet.
- **ETHOCEL** . . for fabricators producing moldings, extrusions, coatings; available also as Ethocel Sheeting.
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ETHOCEL

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CHEMICALS INDISPENSABLE TO INDUSTRY AND VICTORY

DESIGN ABSTRACTS

Captured Enemy Weapons Studied

THE Ordnance Department obtains information concerning the equipment of our enemies through our military intelligence organizations located in all neutral countries, from reports of operations against our enemies in the field and from the study of captured enemy equipment transported home. Young ordnance officers have been specially trained to accompany our fighting organizations to inspect on the battle field all types of captured equipment and to select novel weapons to be transported to the United States for test and study. In many cases these officers, advancing with our troops, have occupied abandoned enemy gun positions while the weapons were literally still hot from firing.

Our studies of foreign weapons have emphasized some of the advantages which have accrued to the enemy due to the long years of engineering preparation for war, which both the Germans and Japanese knew they would fight when they were ready. Through long-range programs extending over ten to twenty years our enemies have been able to prepare fully, from an ordnance standpoint, for the present war and thus able to conduct war on a tremendous scale at a minimum of cost to these nations in raw materials and manpower.

Testing at Proving Grounds

Up to the present time over 4000 tons of enemy equipment have been sent to Aberdeen. These weapons include more than 1500 separate items, principally Japanese and German. They were not secured for the purpose of setting up a museum, but for test at the proving grounds and the laboratories throughout the United States, in the same way that our own ordnance equipment is tested. A large number of rounds of enemy ammunition have been fired to determine muzzle velocities and ranges to enable us to verify their range tables. German artillery is being proof-tested in comparison with our own. In the case of all weapons we are endeavoring to determine whether there are points of superiority, in order that in future design and manufacture we may surely exceed German performance. It is our ambition to know enemy equipment so thoroughly that should the Germans, for example, change the firing pin of one of their many fuses, we will know not only that the change has been made, but the reasons which led to this modification.

Our examination of Japanese army equipment convinces us that Japan does not belong in the "big league". Her weapons lack fire power, and this disadvantage will

prove fatal as we solve the logistic problems and push forward step by step, pressing home our power drives.

The more we study the engineering details of German equipment, the clearer it is that this war was planned for many years—even before Hitler. One of the great advantages of this long period of ordnance engineering planning has been the reduction in the number of components required for German equipment. The reduction of spare parts makes possible the delivery of a greater volume of weapons to the battle fields from a manpower and material standpoint and requires fewer technical troops for maintenance in the field. While Germany held this engineering edge at the beginning, she has now definitely lost this position. Again, she has underestimated the engineering flexibility of our nation. To my mind the greatest possible compliment was paid to American industry by Premier Stalin at his meeting with our President and Mr. Churchill, when he said: "Without American production the United Nations could never have won the war".—*From a talk by Maj. Gen. G. M. Barnes delivered at the War Engineering annual meeting of the S.A.E. in Detroit.*

Controlling Quality of Synthetics

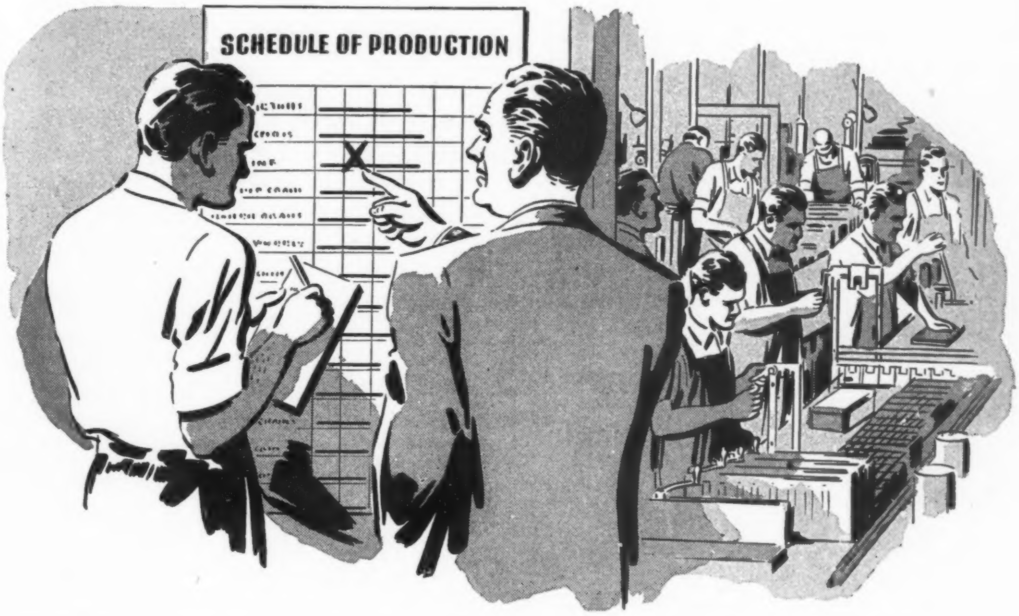
As MORE and more synthetic materials are used, manufacturing problems naturally should be expected to become simpler, except for one factor—we properly demand more service from these new materials, which means holding them to exceedingly close control limits. The trend is toward manufacturing operations which, instead of being controlled by the old type foremen, will be controlled by Ph.Ds. working mass spectrometers. Maybe this is extreme, as ordinary folks seem to quickly grasp the operation of such new tools and our military services are creating a vast reservoir for the future of men trained in handling the much publicized complicated new military devices. After the war the availability of these men should give impetus to the introduction of new control methods in industry.

Offshoot of Atom Smashing

Use of a mass spectrometer for controlling the quality of materials is not as far-fetched as it may seem. This device has just been put on the market in commercial form, and is really an offshoot of our atom-smashing days before the physicists associated with that activity had to stop prying into the constitution of matter and take some part in the perfection of the new type military vacuum tube devices.

The mass spectrometer consists of a semicircular evacuated glass tube with proper attachments at each end, and is located in a strong cross magnetic field. A slight amount of an unknown gas or material is introduced at one end and ionized by a heated filament. These ionized molecules are then electrostatically accelerated into the magnetic field and because of the interaction between the electric charges on the unknown molecules and the magnetic field, they travel in circular paths at terrific speeds. Centrifugal force causes the molecules of heaviest mass to take paths

IS THERE *One Part* IN YOUR PLANT THAT'S A "WALLFLOWER"?



HAS one difficult part become chronically "unpopular" in your production line? Do excessive rejections of certain parts lower the standards of production on other related parts? When V-Day comes, will that troublesome or hard-to-get part hinder your progress?

Contact KAYDON

To make the most of opportunities offered by the new, lighter, stronger metals and plastics . . . to eliminate current problems in war production, or to release capacity for postwar product planning . . . delegate your difficult parts to Kaydon. Here you will find engineering resourcefulness fortified by unusual precision experience . . . to assure maximum production per manhour, and lower costs, on difficult parts. Phone, wire or write . . .

CAPACITY Immediately AVAILABLE for ball and roller BEARINGS Size 6" to 60"

For excellence in production of extremely precise, unusually large ball and roller bearings.

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of larger radii. At the far end of the tube is a slit with, in effect, electrical take-offs at various radii so that the weight of the molecules that are arriving can be conveniently read on electrical instruments.

Instant Results Obtained

At first thought, this may seem like a scientist's laboratory plaything, but it will have an important part in the manufacture of some of the new synthetic rubbers and high test gasolines, because results are obtained instantly in contrast with the hours taken by the conventional methods of chemical analysis. With modern plants operating on the continuous flow plan, thousands of tons of improper products could be made before any off-color product was detected by the older methods. We may reasonably expect that the introduction of the mass spectrometer to control closely other types of manufacturing processes will in the future give us new and more effective materials.—*From a paper presented at a recent meeting of the American Institute of Electrical Engineers, by R. C. Bergvall, assistant to vice president in charge of engineering, Westinghouse Electric & Manufacturing Co.*

Brittle Lacquer Strain Analysis

(*Concluded from Page* 151)

not at the top spoke, where the bending action was the greatest, but about half-way down as shown in the figure. The test was repeated several times with always the same thought-provoking result until the explanation was found in the fact that though the top spoke takes most of the bending, the effect of shear and torsion is greater in the side spokes. Under the cumulative action of these three effects the maximum stress in the piece will occur in one of the side spokes, as demonstrated by the method.

Though the brittle lacquer method is capable of giving alone all necessary information regarding stress conditions in machine parts, its use in deriving dependable numerical values for the stresses necessitates a great number of most carefully conducted tests. On the other hand, if only the place and direction of the maximum stress in the piece is required, this can be obtained with comparative ease and usually by a single test. For this reason some experimenters are inclined to use the brittle lacquer method rather qualitatively, that is, to locate the danger points in the specimens and after they are obtained to complete the test with accurate strain gage measurements. Which one of these methods to use may depend greatly on the nature of individual problems. However, whether brittle lacquer is used quantitatively or only qualitatively, it has already proved to be a welcome aid to the stress analyst of today.

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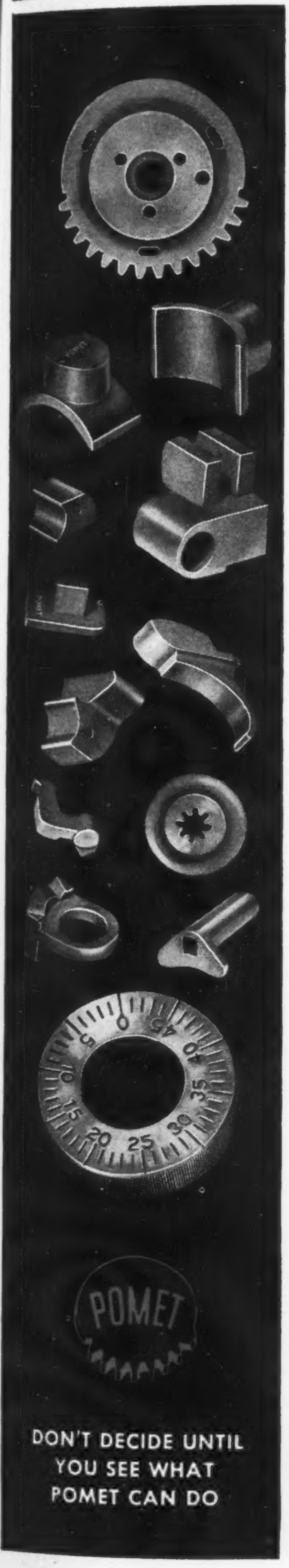
POWDER METALLURGY

TO SERVE YOU BETTER

POWDER METALLURGY Inc. has become a subsidiary of GENERAL BRONZE CORPORATION and is now operating with new and enlarged facilities under the name of POWDER METALLURGY CORPORATION.



Save TIME AND MONEY

IN THE QUANTITY PRODUCTION OF SMALL METAL PARTS

WITH POMET

Under the stress of war-time demands, this plant has sped the development of powder metallurgy from the pioneer phases of a new process to practical production routines. Today Pomet parts are saving time, material and labor for many manufacturers who wish to combine high standards with quantity production. A wide variety of complicated parts can be produced quickly and economically using brass, bronze, aluminum, ferrous alloys and other metals, combinations of metals or metals combined with non-metallic powders.

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- **CLOSE TOLERANCES WITHOUT MACHINING** In many cases, finished pieces can be held to tolerances of plus or minus .001" or even closer, with all or most of the need for expensive machining eliminated.
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New and greatly expanded facilities now assure even faster production. Technical excellence is being maintained and constantly improved. In quantities of 20,000 and over Pomet parts are particularly interesting to manufacturers who have to keep cost in line with rigid specifications. We will be pleased to quote on blueprints and specifications, and are in a position to give you exceptional service. We shall also be glad to send interesting and informative literature on request.

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Business and Sales Briefs

PHILADELPHIA GEAR WORKS has appointed James N. Morrell sales manager, and Thomas V. Withington, assistant sales manager of the Limitorque Valve Control division. William F. Plume replaces Mr. Withington as chief engineer, while Robert E. Richards becomes assistant chief engineer.

♦

Recent announcement has been made of the appointment of E. A. Green as general assistant to the manager, motor division, General Electric Co., Schenectady, N. Y.

♦

Transfer of assistant manager Ford Brown from Milwaukee to the Minneapolis office of Blackmer Pump Co., Grand Rapids, Mich., has been announced. Formerly Mr. Brown had worked in the engineering and sales departments at the Grand Rapids plant.

♦

Former sales manager of Cambridge Rubber Co., John S. Weare, has been made vice president of Cambridge Rubber Sales Corp.

♦

P. F. Zerkle has been chosen to direct sales activities of Michigan Tool Co., Detroit. The company is also establishing branch offices in Cleveland and Dayton. George Pierce is district manager of the Cleveland branch, located in the Penton building; and H. E. Roedter, the Dayton branch at 710 Harries building.

♦

Resigning as west coast representative for the steel division of War Production Board, Thomas L. Moore has resumed his former position as Pacific coast district manager with Rustless Iron & Steel Corp.

♦

In addition to his position as president of American Brakeblok division, American Brake Shoe Co., Detroit, William A. Blume has been elected a vice president of the parent company in New York.

♦

With the company since 1909, Bruce W. Bennett succeeds Frederick Connell, who has retired after forty-five years service, as assistant general manager of sales, American Steel & Wire Co.

♦

According to a recent announcement, Donald S. Klippert has been made assistant general manager of sales of Timken Steel & Tube division, Timken Roller Bearing Co., Canton, O. Robert P. Donnell, metallurgical engineer specializing in aircraft applications, has assumed the position of Cleveland district manager formerly held by Mr. Klippert.

♦

As general manager of industrial sales of Libbey-Owens-Ford Glass Co., J. M. Johns succeeds the late G. L. Conley.

♦

Five new sales engineering organizations have been chosen to represent Graham Transmissions, Inc., Milwaukee. These are: Frank Campbell Coe, Commercial Trust building, Fifteenth and Market streets, Philadelphia; John B. Foley Jr., Co., 249 Erie boulevard, Syracuse, N. Y.; Paul M. Kline, 2030 East Twenty-second street, Cleveland; Bruce W. Rogers, P. O.

Box 172, 850 South High street, Akron, O.; D. W. Smith, 149 Broadway, New York.

♦

Former assistant manager of Goodyear Research Laboratory, Herman R. Thies has been promoted to manager of Goodyear Tire & Rubber Co., plastics and chemical sales division at Akron.

♦

Succeeding Charles A. Carlson, who has resigned to form his own company to manufacture the Carlson internal combustion engine, is Pinkney W. Love as manager of the Washington office of Lukens Steel Co. and its subsidiaries, By-Products Steel Corp. and Lukenweld Inc., Coatesville, Pa.

♦

Under the supervision of John Altmayer, the Mec-Rad division of Black Industries, Cleveland, has been formed to manufacture mechanical components of all types of radionic devices.

♦

Building of a foundry for production of permanent mold aluminum castings is being planned by Grand Rapids Castings Co., Grand Rapids, Mich. President of this newly formed company is Donald G. Denison.

♦

Appointment of R. P. Tyler as general manager of sales and C. R. Deam as assistant manager of sales has been announced by A. Leschen & Sons Rope Co., St. Louis.

♦

Formerly research chemist and metallurgical assistant at American Rolling Mill Co., F. L. Meacham has been named manager of sales of Chicago Vitreous Enamel Products Co., Cicero, Ill.

♦

Lack of material and manpower for building a plant at Burbank, Calif., has made necessary the leasing of the Hollywood Aluminum Products Co. plant in Hollywood by Ampco Metal Inc., Milwaukee.

♦

Election of Charles L. Turner as vice president in charge of sales, Buffalo Bolt Co., North Tonawanda, N. Y., has been announced. Mr. Turner has replaced A. Maxwell Jones, who resigned recently.

♦

Assistant sales manager of American Pulley Co., Philadelphia, for the past fifteen years, Frank E. Brown succeeds Archie Chandler as general sales manager. Mr. Chandler is retiring from active sales management of the company but will continue as vice president. He will take charge of sales on the West Coast.

♦

Plans for constructing a new plant near Corpus Christi, Texas, have been announced by The Celanese Corp. of America. It is expected to go into operation the latter part of next year and, when completed, will be the eighth plant owned and operated by the company.

♦

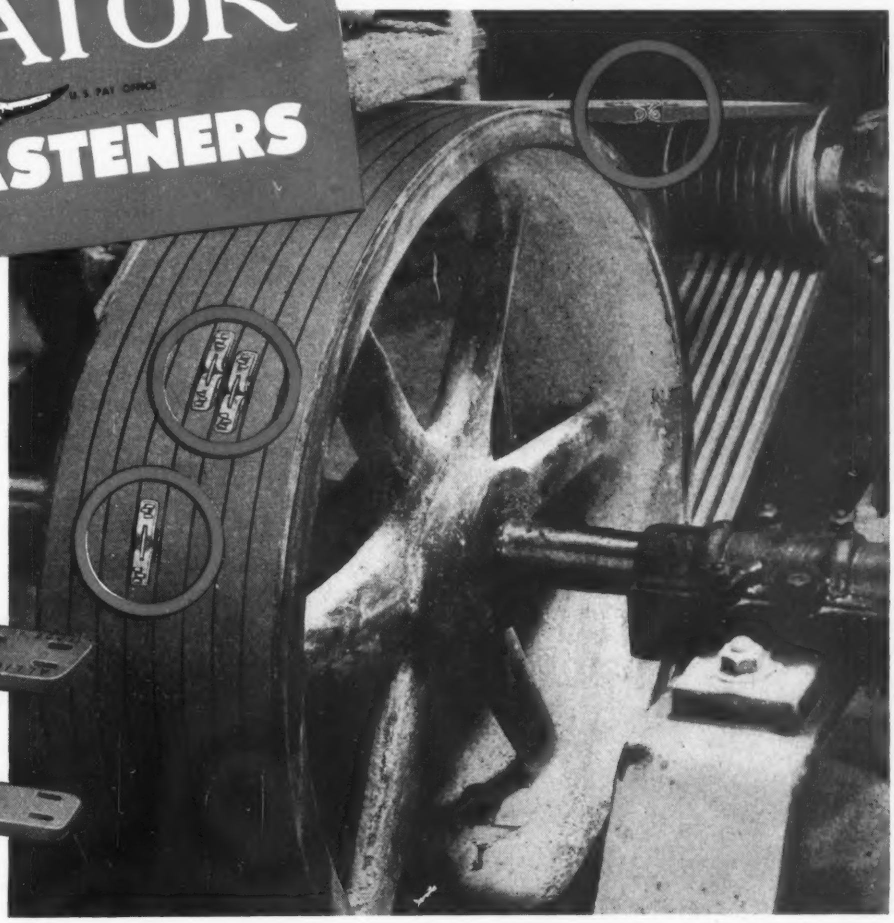
With B. F. Goodrich Co. since 1931, Edward H. Fitch has been appointed merchandise manager of the combined automotive, aviation and government sales divisions.

♦

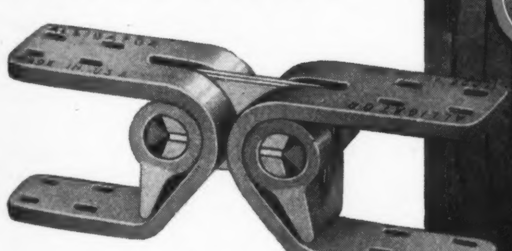
Several appointments have been announced by Peter A. Frasse & Co. Inc. These are: Russell B. Barnett has been promoted from Philadelphia district manager to vice president in charge of company sales in New York. Formerly assistant manager, Val Hansel has been made manager of the New

ALLIGATOR
TRADE MARKS REG. U.S. PAT. OFFICE
V-BELT FASTENERS

Close coupled drives to shafting of the type shown below are now made possible through the use of Alligator V-belt fasteners and fabric core V-belting. These fasteners are, however, not for application to endless cord V-belts.



—widen field of application for V-Belts



D Fastener actual size

WITH the rapidly increasing use of V-belts and the constantly widening field for applications of these belts there has come an insistent demand for a fastened V-belt.

To meet this demand, belting manufacturers have put on the market leather V-belts and specially constructed fabric V-belts. The Flexible Steel Lacing Company, as its part of the program, developed the Alligator V-belt fastener.

With the Alligator V-belt fastener and the specially constructed V-belt, it is convenient and economical to install and maintain matched multiple lengths of V-belts on drives without the necessity of dismantling expensive installations. It is also possible to make up a wide variety of multiple V-belt drives from roll belting. Only one fastener is needed on each belt but if some odd lengths of belting are on hand, they can be used by joining them with several fasteners.

During the nine years these fasteners have been on the market they have established a remarkably fine performance record on a wide variety of drives. You can therefore use these fasteners on your V-belt drives with assurance as to their successful operation.

The fasteners are available for B, C and D sizes of belt for industrial use and 1-in. and 2-in. sizes for railroad use. Complete details are covered in the bulletin described below and if you are not familiar with this latest development in belt fastening practices we suggest you write for a copy.

COMPLETE DETAILS are covered in Bulletin V-205 which covers both industrial and railway applications of Alligator V-belt Fasteners. Shows where and how they are used with sizes, list prices, tools and other details.

A copy will be mailed at your request

Order from Your Supply House

FLEXIBLE STEEL LACING CO.
4686 Lexington St., Chicago 44, Illinois

Sole manufacturers of Alligator Steel Belt Lacing for flat transmission belts • Flexco HD Belt Fasteners for conveyor belts • Alligator V-belt Fasteners for open and V-belting.

York sales department. John D. Drummond has been promoted from assistant manager to manager in Philadelphia, and Leslie N. Stetson has been named manager of the Buffalo district.

♦

According to an announcement by Briggs Clarifier Co., Henry T. Moore has been appointed general sales manager of the newly organized automotive division, and E. K. Burgess and J. H. Nash, assistant managers of the new industrial division.

♦

The American Steel & Wire Co., subsidiary of U. S. Steel Corp., has announced the naming of E. A. Murray as assistant manager of the manufacturing sales department in the Chicago office.

♦

Appointment of F. E. Phillips as vice president in charge of sales has been announced by Gemmer Mfg. Co., Detroit.

♦

Recent announcement has been made that Perry C. Goodspeed, connected with Industrial Synthetics, Inc., Irvington, N. J., now represents that company in California. His address is Synthetics Corp., 445 West Cannon Drive, Beverly Hills, Calif.

♦

Barto Attig has succeeded John W. Lougheed as Detroit representative for American Insulator Corp., New Freedom, Pa.

♦

The Chandler-Evans Corp., manufacturers of accessories used in airplane engines, has recently been acquired by Niles-Bement-Pond Co. Plants are located at South Meriden and Wallingford, Conn., and Dayton. Charles W. Deeds remains president, while B. H. Gilpin becomes vice president and general manager, in charge of activities at the South Meriden plant.

♦

Formerly branch manager of Schacht Motor Co., Joseph D. O'Flaherty has been named assistant manager in charge of sales and promotion of United States Electrical Tool Co., Cincinnati.

♦

J. C. Vignos, former director of research and assistant executive vice president, has succeeded H. A. Landon as general manager of sales of Ohio Ferro-Alloys Corp., Canton, O. Mr. Landon has been named Pacific Coast representative.

♦

Promotion of Carl C. Nelson from engineer to manager of the control division of Electric Machinery Co., Minneapolis, has been announced.

♦

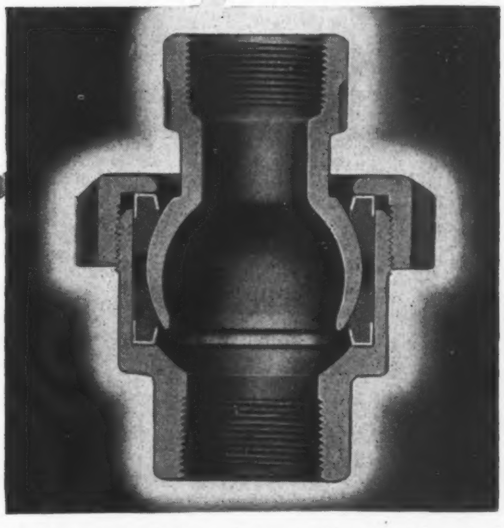
Succeeding John F. Hazen who has retired because of ill health is Ralph E. Sharp as manager of sales, wire and wire products division, Bethlehem Steel Co., Bethlehem, Pa.

♦

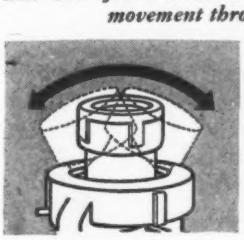
With the company since 1941, John S. Garraway has been appointed sales manager of the hydraulic division, Adel Precision Products Corp., Burbank, Calif. Previously Mr. Garraway had operated his own hydraulics parts manufacturing company.

♦

To provide better service to war plants Cannon Electric Development Co., Los Angeles, has announced the following engineering representatives: E. B. Glenn, 801 Healey building, Atlanta; Douglas H. Loukota, 10 Light street, Baltimore; Ray Perron & Co., Little building, Boston; H. M. Welch,



Not just a swivel joint... but a combination of a swivel and ball joint with rotary motion and responsive movement through every angle.



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No trouble with shock, movement, vibration, expansion and contraction... IF YOUR PIPES ARE PROTECTED by Barco all-movement Flexible Joints! You can turn them, twist them, bend them, flex them... but you can't loosen them! They have been doing it for thirty years! Let us show you how Barco Flexible Joints can be engineered to answer your liquid conveying problems. Write to: Barco Manufacturing Company, Not Inc., 1806 Winnemac Avenue, Chicago 40, Illinois.

BARCO *FLEXIBLE JOINTS*

"MOVE IN EVERY DIRECTION"

Crosby building, Buffalo; George Sturman, 712 Sixth avenue, Minneapolis; J. Tinsley Smith, 108 Seventeenth avenue, Nashville; J. W. Beneke, St. Louis agent for E. L. Melton, at 575 Arcade Building, St. Louis.

Sales manager A. C. Dyer has been elected vice president of the Electric Controller & Mfg. Co., Cleveland. He will also continue with his former activities.

The appointment of J. C. Blake as general sales manager has been announced by Riverside Metal Co., Riverside, N. J. Mr. Blake was formerly priority manager.

Opening of a new Chicago office in the LaSalle-Wacker building, 221 North LaSalle street, has been announced by Boots Aircraft Nut Corp. William F. Arnoldy, head of the Detroit office, has been placed in charge and will make his headquarters in Chicago.

MEETINGS AND EXPOSITIONS

Feb. 20-24—
American Institute of Mining and Metallurgical Engineers. Annual meeting to be held at Waldorf-Astoria hotel, New York. Frank T. Sisco, 29 West Thirty-ninth street, New York 18, is secretary of the metals division.

Feb. 21-22—
Society of the Plastics Industry. Pacific Coast Section conference to be held at Ambassador hotel, Los Angeles. James D. McDonald, 544 East Thirty-first street, Los Angeles 11, is chairman of the Pacific Coast Section.

Feb. 22-23—
American Society for Testing Materials. Symposium on plastics to be held in Philadelphia: the first session at Franklin institute on Feb. 22, and the second at Benjamin Franklin hotel on Feb. 23. Robert J. Painter, 260 South Broad street, Philadelphia 2, is assistant to the secretary.

Feb. 28-March 3—
American Society for Testing Materials. Spring meeting to be held at the Netherland Plaza, Cincinnati. Robert J. Painter, 260 South Broad street, Philadelphia 2, is assistant to the secretary.

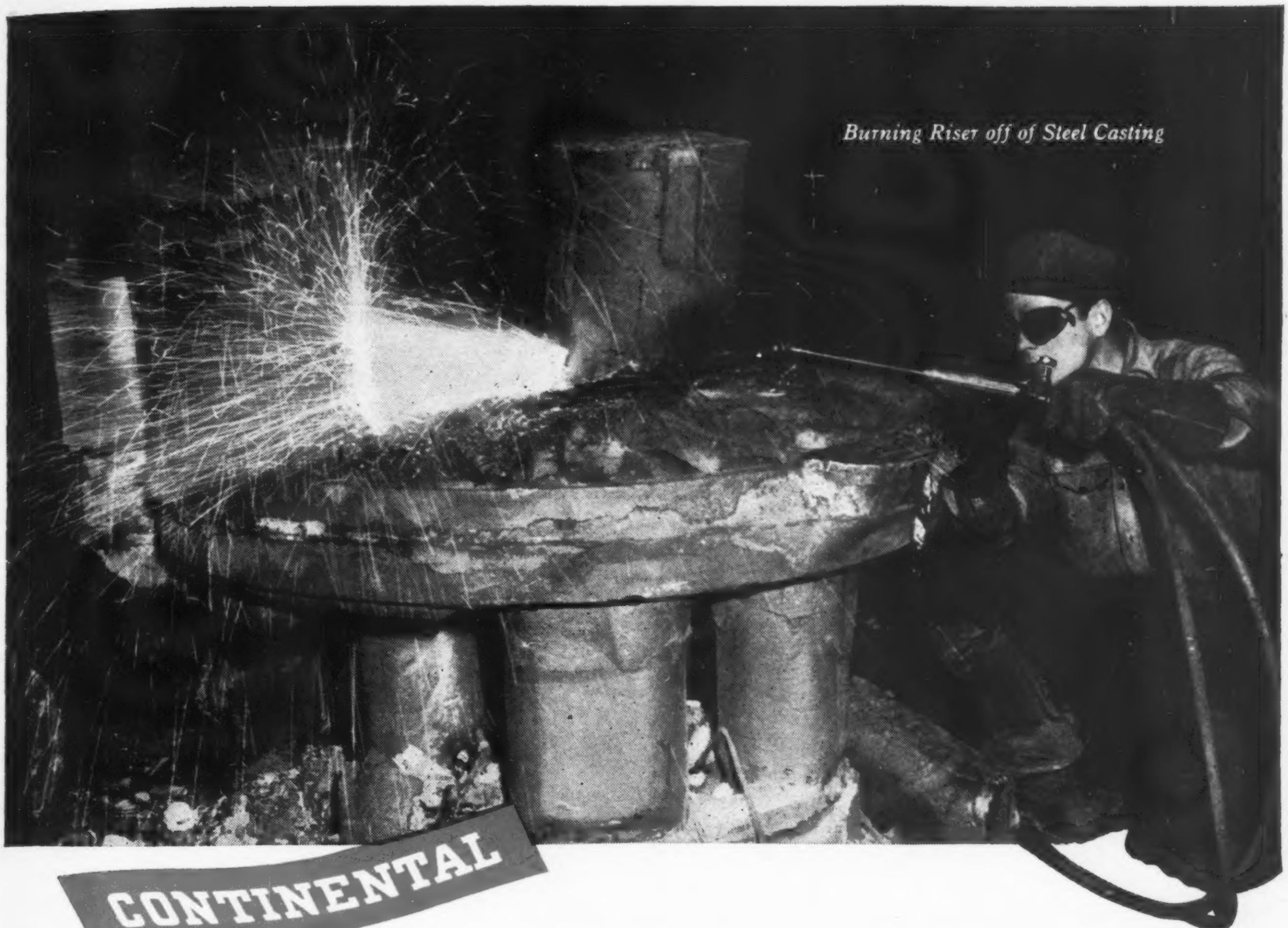
March 26-28—
American Society of Tool Engineers. Annual meeting to be held at Bellevue Stratford hotel, Philadelphia. Headquarters are at 2567 West Grand boulevard, Detroit.

April 1-3—
American Society of Mechanical Engineers. Spring meeting to be held at Birmingham, Ala. Additional information may be obtained from headquarters at 29 West Thirty-ninth street, New York. C. E. Davies is secretary.

April 2-5—
American Ceramic society. Second war congress and forty-sixth annual meeting to be held at Hotel William Penn, Pittsburgh. Ross C. Purdy, 2525 North High street, Columbus, O., is general secretary.

April 12-15—
Electrochemical society. Spring meeting to be held at Hotel Pfister, Milwaukee. Colin G. Fink, 3000 Broadway, New York, is secretary.

April 25-28—
American Foundrymen's association. Third war production foundry congress and show to be held in Buffalo. The exhibit will be shown at Buffalo Memorial Auditorium. R. E. Kennedy, secretary, 22 West Adams street, Chicago, is secretary.



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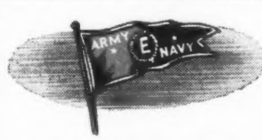

This is 1944! What can we do to make it the Victory Year? The goal . . Victory. The place . . Europe. The time . this year. The responsibility . . Ours.

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They Say . . . .

"'When will the war end?' That's the first question almost everyone asks. I have said that what we ought to do is think far less about when the war will end, and more about how to end it. The question is a very natural one, and while everyone is entitled to his or her guess, I feel that everyone will recognize the fact that it is bound to end sooner rather than later if we continue full speed ahead on every front, whether it be men fighting the enemy in the trenches, or men-o-war fighting on the high seas, or men in the offices, on the farms, in the mines, and in the factories, fighting their producing opposites in the enemy country on the essentials to wage war.

"Regardless of the enemy's condition, the more unrelenting, the greater the pressure, the sooner shall he be defeated. The greater the production at home, the greater can that unrelenting pressure be kept on the enemy on land, in the air, and on the sea. The very fact that the enemy agents can report no slackening up in our effort on the home front, but that the nation is in high gear and producing to its limit, will of itself be a powerful factor toward convincing him sooner or later of his accelerating deteriorating position."—Admiral Harold R. Stark.

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"With our biggest battles coming up, this emphatically is not the time to divert any substantial quantities of materials, labor or facilities to less essential civilian production. There certainly cannot be any return to volume production of less essential goods until the war picture is a great deal clearer."—Donald M. Nelson.

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"On the other hand, government-financed development of new products, though necessary in war, is so un-American as to be unthinkable in peacetime. For it is in just this field of new development that private initiative is most efficient, while government—though an effective agent for furnishing the common services that have become standardized—is very unsuited to operations which require initiative and judgment."—Dr. Albert W. Hull.

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"The physical limitations on the ability to introduce new designs and new products in the early postwar period are self-evident. Yet it is important that we move forward as rapidly as circumstances permit. Technology has advanced in the war years. We can do a better job. Better technique should enable us to lower prices and thus stimulate consumption and employment. If industry could now be assigned material for research and engineering development in those instances where it would not detract from the war effort, it would help speed up the introduction of new designs of existing things as well as of new things. The amount of material required for this purpose would be negligible in relation to the total. This should be done."—Alfred P. Sloan Jr.